Appendix C

Analysis of Effects of Proposed Action and Reasonable and Prudent Alternative on Species-Level Biological Requirements of Listed Species

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Acronymns

NMFS	National Marine Fisheries Service
ESUs	evolutionarily significant units
Draft BiOp	Draft FCRPS Biological Opinion (July 27, 2000)
FCRPS	Federal Columbia River Power System
SAR	smolt-to-adult returns
PUD	public utility district
TAC	Technical Advisory Committee (of U.S. v Oregon)
wy	water year
CRI	Cumulative Risk Initiative
QAR	Quantitative Analytical Report
PATH	Plan for Analyzing and Testing Hypothesis
SIMPAS	Simple Passage (model)
RPA	reasonable and prudent alternative
SR	Snake River
UCR	Upper Columbia River
QAR	Quantitative Analytical Report

C.1 Purpose

This appendix documents the analysis the National Marine Fisheries Service (NMFS) used to estimate effects of a proposed action on the species-level biological requirements of listed Columbia River basin evolutionarily significant units (ESUs). Quantitative analytical results are one of several sources of information used to determine whether a proposed action jeopardizes listed species. Section 6.1.2 of the July 27, 2000, Draft Federal Columbia River Power System (FCRPS) Biological Opinion include an overview of analytical methods, and Sections 6.3, 9.7.2, and 9.7.3.2 of the Biological Opinion contains summaries of the analytical results. The Biological Opinion references this appendix as a source of additional details regarding those sections.

C.2 Indicator Metrics

Section 1.3.1.1 of the Biological Opinion describes the general analytical approach that NMFS uses to apply the jeopardy standard in the implementing regulations (§402.02 - definition of "jeopardize the continued existence"). This general analytical approach states that, for an action to avoid jeopardy, the mortality of listed salmonids within the different ESUs attributable to the action must be low enough to meet following conditions.

! When combined with mortality occurring in other life stages, there is a **high likelihood of population survival** and a **moderate to high likelihood of population recovery**,

or, in the absence of a recovery plan, or similar analysis,

! Mortality in the action area is no higher than that which would occur in the absence of the action (i.e., **full mitigation**).

Most of the Columbia basin ESUs rely entirely on a qualitative approach to this determination. For several of the ESUs, however, it is possible to quantify key aspects of the population dynamics and expected effects of the proposed action. These quantifications are imperfect, but NMFS considers them useful for organizing facts and hypotheses to support the general analysis. For these ESUs, NMFS considers the quantitative component of the analysis, along with other qualitative factors, when making a jeopardy determination.

In Section 1.3.1.2, NMFS identified "indicator metrics" that are useful for evaluating the general analytical approach described in Section 1.3.1.1. Table C-1 describes the three indicator metrics and the quantitative approximations of acceptable risk levels.

Table C-1. Summary of indicator metrics.

	Survival	Recovery	Full Mitigation
Applies to:	All actions, including operation of the FCRPS, in combination	All actions, including operation of the FCRPS, in combination	Operation of the FCRPS, possibly in combination with off-site mitigation
Metric:	1 - the probability of absolute extinction in 24 and 100 years	1 - the probability that 8-year geometric mean abundance will be ≥ recovery abundance level in 48 and 100 years	(Juvenile * Adult) passage survival through the action area
Acceptable Risk:	High probability (approximated as 5% or less risk of extinction)	Moderate to high probability (approximated as 50% or greater likelihood of meeting the recovery abundance level in the specified time period)	Must equal the natural survival rate that would occur in the absence of FCRPS effects

C.3 Methods

C.3.1 General Approach

NMFS applied a quantitative analysis of species-level biological requirements to five Snake River (SR) and Upper Columbia River (UCR) ESUs (SR spring/summer chinook, SR fall chinook, SR steelhead, UCR spring chinook, and UCR steelhead). Briefly, the analysis includes the steps illustrated in Figure C-1. The general approach is discussed in the four steps presented below.

Step 1) Define the change in survival needed to meet the approximation of acceptable risk for each indicator metric. The starting points for evaluating the indicator metrics are as follows:

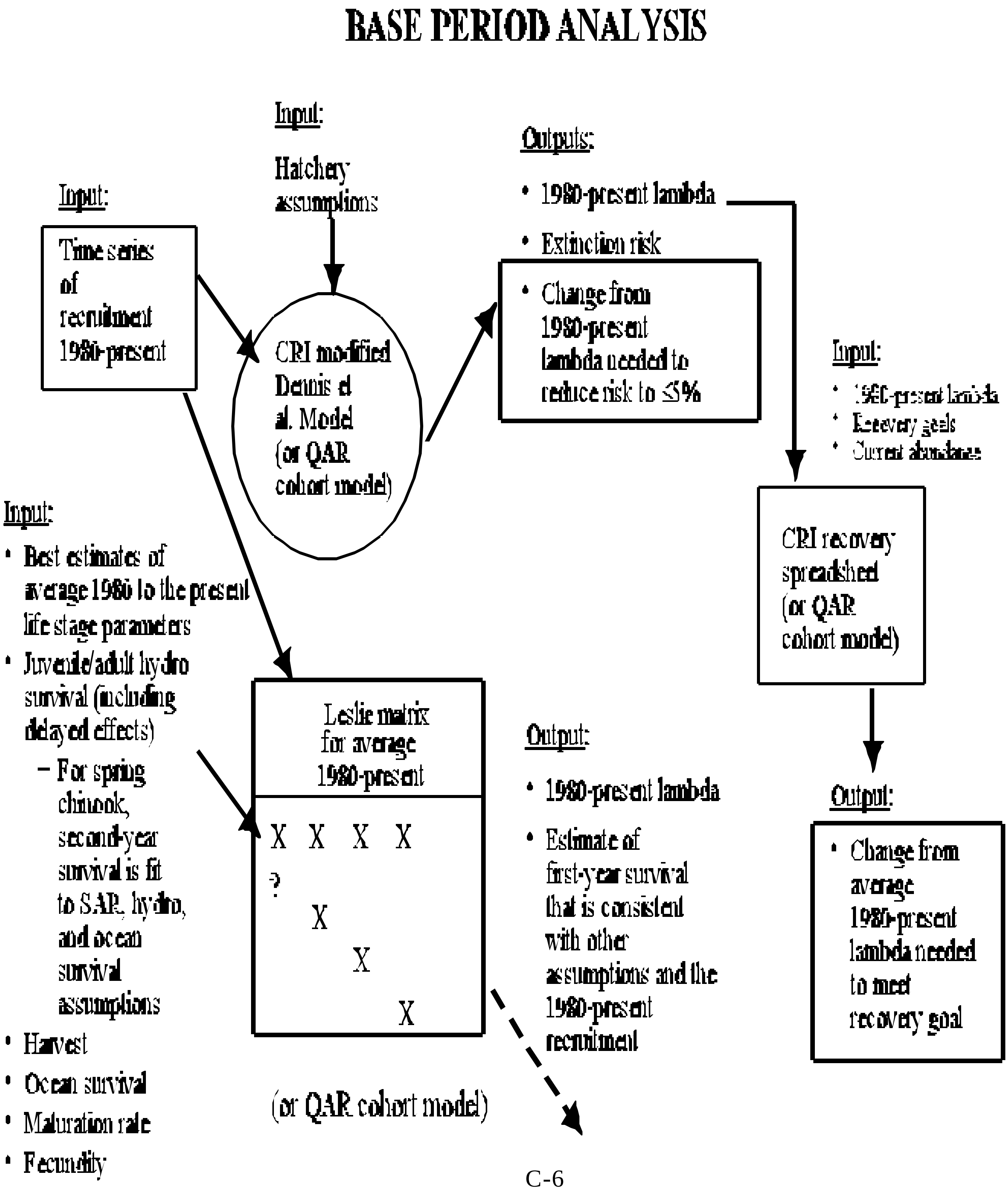
! The Cumulative Risk Initiative (CRI) Columbia basin analysis (McClure et al. 2000), which provided survival metric estimates for populations in all five ESUs

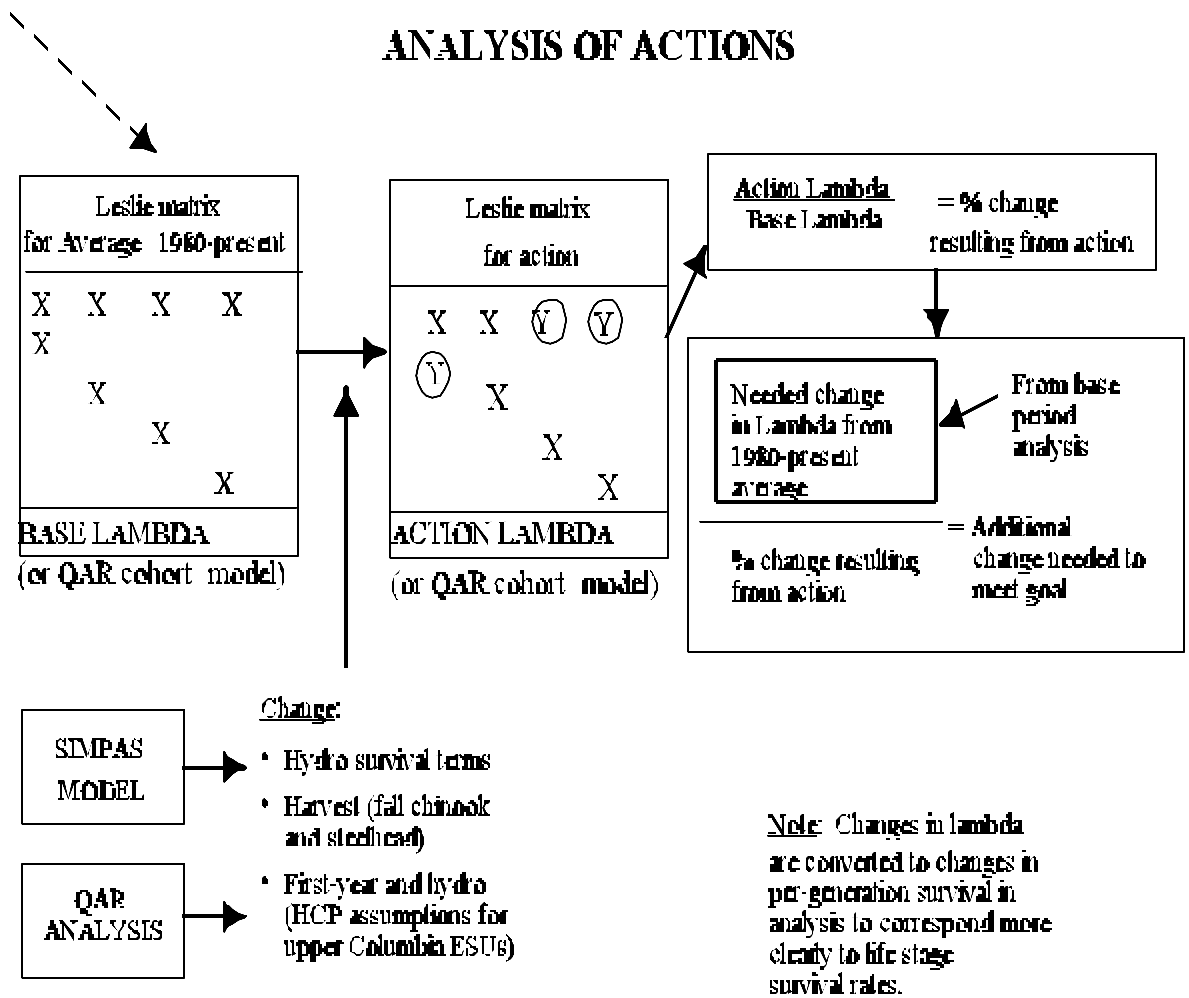
! Ancilliary CRI analyses (McClure 2000), which provided recovery metric estimates for the four ESUs for which recovery abundance levels have been proposed

! The Upper Columbia River Quantitative Analytical Report (QAR; Cooney 2000), which provided estimates of both the survival and recovery metrics for UCR spring chinook and UCR steelhead

! Annex 1 to this appendix, which describes NMFS' best estimates of natural survival rates through the FCRPS for each of the five ESUs

Figure C-1. Schematic of methods used to estimate necessary survival changes and to compare these changes with expected survival changes resulting from a proposed action (see text for details).




ANALYSIS OF ACTIONS
Leslie matrix for Average 1980-present
X X X X
X
X
X
X
BASE LAMBDA
(or QAR cohort model)
Leslie matrix for action
X X Y Y
Y
X
X
X
ACTION LAMBDA
(or QAR cohort model)
Action Lambda
Base Lambda
= % change resulting from action
Needed change in Lambda from 1980-present average
From base period analysis
% change resulting from action
= Additional change needed to meet goal
SIMPAS MODEL
QAR ANALYSIS
Change:
• Hydro survival terms
• Harvest (fall chinook and steelhead)
• First-year and hydro (HCP assumptions for upper Columbia ESUs)
Note: Changes in lambda are converted to changes in per-generation survival in analysis to correspond more clearly to life stage survival rates.

For the survival and recovery indicator metrics, these reports defined the change in annual population growth rate (λ, "*lambda*") needed to reduce risk to the acceptable levels described in Table C-1. Two models were used to generate these estimates: CRI applied a modified Dennis et al. (1991) diffusion model (Holmes 2000, in review), and QAR applied a modified Botsford and Brittnacher (1998) cohort replacement model. QAR estimates were also reported as changes in per-generation survival. NMFS converted the CRI-estimated changes in λ to needed changes in per-generation survival (egg-to-adult spawner survival) to place the needed survival change into the same units as the life-stage survival rates estimated in Steps 2 and 3.

The full mitigation indicator metric applies only to survival through the FCRPS, rather than to survival through the full life cycle. Annex 1 describes the methods NMFS used to estimate juvenile and adult survival (multiplied together for convenience) that would probably occur in the absence of the FCRPS. This is referred to as "natural survival." The increase in survival needed to achieve the natural survival rate is simply the (juvenile * adult) natural survival rate divided by the (juvenile * adult) survival rate associated with a given action.

Step 2) Define the life-stage-specific survival rates that correspond to the adult return observations included in the risk assessment. For survival and recovery metrics, NMFS based the risk assessment in Step 1 on abundance and trends in adult returns during a series of recent years. This series of years is a "base period." For most ESUs, the 1980 brood year through the most recently available return year represented the base period. To evaluate how new actions that affect only certain life stages would change the base period risk, NMFS first estimated the mean survival rate in each of those life stages during the base period. Where possible, a simple deterministic Leslie (1945, 1948) matrix was set up to represent the best estimates of average survival through all but one life stage during the base period. This matrix also incorporated age-specific maturity rates and fecundity estimates. The one unknown survival rate was adjusted so that the overall combination of estimated life-stage survival rates fit the average base period spawner return observations (Euler equation; Ratner et al. 1997; McClure et al. 2000). The fully parameterized matrix was then used to estimate the annual population growth rate at equilibrium by solving for the dominant eigen value (Caswell 1989). This method is valid as long as there is no density-dependence, which CRI confirmed for Snake River spring/summer chinook at population levels observed during the last 20 years (McClure et al. 2000).

For the full mitigation indicator metric, NMFS estimated the arithmetic average (juvenile * adult) passage survival during the base period to complement the base period survival and recovery analysis. For UCR spring chinook and UCR steelhead, NMFS applied QAR estimates of total (transported and non-transported) juvenile survival and adult survival during the base period. For Snake River ESUs, NMFS applied base period juvenile passage survival estimates from the Plan for Analyzing and Testing Hypotheses (PATH; Marmorek et al. 1998; Peters et al. 1999) and adult survival estimates described in the Draft Biological Opinion (Table 6.1-1).

Step 3) Define the life-stage-specific survival rates associated with the hydrosystem action and with expected survival in other life stages; estimate the proportional change from base survival. NMFS estimated FCRPS juvenile and adult survival resulting from the proposed action and the reasonable and prudent alternative (RPA) using methods defined in Section 6.1.1 of the Draft Biological Opinion. These methods included use of NMFS' Simple Passage (SIMPAS) spreadsheet to estimate juvenile survival through the hydrosystem (Appendix B). NMFS also estimated expected survival in other life stages, based on actions defined in the All-H Paper (NMFS 2000a).

For the survival and recovery indicator metrics, the relevant survival terms in the base matrix were then updated to reflect the expected changes. A new per-generation survival rate, representing the combination of the various life-stage survival changes, was estimated with the new matrix. Three action matrices were produced in the Draft Biological Opinion. A current matrix represented the proposed FCRPS action and expected survival changes in other life stages. An RPA matrix represented the hydrosystem component of the RPA and expected survival changes in other life stages. A breach matrix represented the survival following a four-dam Snake River breach and expected survival changes in other life stages. In each case, the estimate of per-generation survival associated with the action was divided by the average base period per-generation survival to determine the expected proportional increase in survival resulting from the specified action.

For the full mitigation indicator metric, NMFS estimated the (juvenile * adult) passage survival associated with the hydrosystem action under consideration and then divided this by the base (juvenile * adult) survival rate to determine the expected proportional change.

Step 4) Compare the proportional change in survival resulting from the proposed action with the needed change defined in Step 1. NMFS derived ratios ([Needed Change From Step 1]÷[Expected Change From Step 3]) to indicate the degree to which the proposed action reduces risk to the levels described in Table C-1. Ratios less than or equal to 1.0 indicate that the risk has been adequately mitigated according to the criteria in Table C-1. Ratios greater than 1.0 indicate that additional improvements in survival are necessary to achieve the risk levels identified in Table C-1. These values represent the multiplier by which the expected survival rate must be increased.

C.3.2 Estimates of Needed Improvement From Base Period Survival

The following two subsections discuss the survival and recovery metrics, as well as the full mitigation indicator metric comprising the general analytic approach.

C.3.2.1 Survival and Recovery Indicator Metrics

Tables C-2 through C-5 display estimates of the needed improvement from base period survival for the four survival and recovery indicator metrics. All results are expressed as multipliers to either annual population growth rate (λ) or per-generation (egg-to-adult spawner) survival.

CRI estimates of the changes in annual population growth rate needed for the survival metrics are from McClure et al. (2000, Appendix B). Methods are described in McClure et al. (2000). CRI estimates of survival changes needed for the recovery metrics are from McClure (2000). Methods associated with these estimates are described in Schiewe (2000). Because that document is not easily accessible, the CRI recovery method is briefly described here. Needed changes in annual population growth rate were calculated using Equation 1:

(1) $\boldsymbol{\lambda}_{needed} = (\boldsymbol{n}_{goal} \div \boldsymbol{n}_{current})^{(1\,/\,\mathbf{t})}$

Where:

$\boldsymbol{\lambda}_{needed}$ is the geometric mean annual population growth rate that would yield the desired population size in the desired time; $\boldsymbol{n}_{\mathrm{goal}}$ is the proposed recovery goal (expressed as the 8-year geometric mean of spawner numbers); $\boldsymbol{n}_{current}$ is the current number of spawners (expressed as the geometric mean of the most recent 8 years); and $\boldsymbol{t}$ is the time period (44 or 96 years) over which recovery goals are to be achieved (44 and 96 are used rather than 48 and 100, since the recovery goal is an 8-year geometric mean).

The necessary percent improvement in population growth rate to achieve recovery goals in the allotted time was then calculated using the ratio of the needed growth rate to the current growth rate. This method assumes that population growth is density-independent.

All CRI estimates of the multiplicative change in annual population growth rate (Δλ) were converted to a multiplicative change in per-generation (egg-to-adult spawner) survival rate (ΔS) according to Equation 2 using mean generation times (in years) listed in Tables C2 to C5:

(2) $\Delta S = \Delta\lambda^{\text{Mean Generation Time}}$

For example, Table C-2 indicates that the base λ must be multiplied by 1.05 for the Imnaha index stock, given an assumption of 20% hatchery spawner effectiveness and a base period of 1980 to the most recently available return year (1999). The average generation time of the Imnaha stock is 4.56 years, which means that the 1.05 change must be applied to the annual survival rate for each of those 4.56 years. To determine the necessary change over the lifetime of an Imnaha River salmon, the egg-to-spawner survival rate (or any survival rate contributing to this) must be multiplied by $1.05^{4.56}$, which is equal to 1.25, to achieve a 5% risk of extinction in 24 years.

Table C-2. Needed incremental change from base period survival to achieve 5% risk of extinction in 24 years.

		Hatchery Spawner Effectiveness = 20%								Hatchery Spawner Effectiveness = 80%							
		1980 to Most Recent				1980 to Projected 2004				1980 to Most Recent				1980 to Projected 2004			
ESU	Mean Gen.	CRI		QAR		CRI		QAR		CRI		QAR		CRI		QAR	
Population	Time	Δλ	ΔS	Δλ	ΔS	Δλ	ΔS	Δλ	ΔS	Δλ	ΔS	Δλ	ΔS	Δλ	ΔS	Δλ	ΔS
Snake Spring/ Summer Chinook																	
Bear Valley	4.52	1.00	1.00			1.00	1.00			1.00	1.00			1.00	1.00		
Imnaha	4.56	1.05	1.25			1.00	1.00			1.61	8.65			1.46	5.62		
Johnson	4.52	1.00	1.00			1.00	1.00			1.00	1.00			1.00	1.00		
Marsh	4.54	1.00	1.00			1.00	1.00			1.00	1.00			1.00	1.00		
Minam	4.52	1.17	2.03			1.05	1.22			1.69	10.59			1.47	5.71		
Poverty	4.52	1.00	1.00			1.00	1.00			1.00	1.00			1.00	1.00		
Sulphur	4.50	1.07	1.36			1.00	1.00			1.07	1.36			1.00	1.00		
Snake Fall Chinook	4.12	1.00	1.00							1.26	2.55						
Snake Steelhead																	
A-Run	4.00[1]	1.36	3.42							3.17	100.98						
B-Run	4.00[1]	1.48	4.80							3.52	152.65						

		Hatchery Spawner Effectiveness = 20%								Hatchery Spawner Effectiveness = 80%							
		1980 to Most Recent				1980 to Projected 2004				1980 to Most Recent				1980 to Projected 2004			
ESU	Mean Gen.	CRI		QAR		CRI		QAR		CRI		QAR		CRI		QAR	
Population	Time	$\Delta\lambda$	ΔS	$\Delta\lambda$	ΔS	$\Delta\lambda$	ΔS	$\Delta\lambda$	ΔS	$\Delta\lambda$	ΔS	$\Delta\lambda$	ΔS	$\Delta\lambda$	ΔS	$\Delta\lambda$	ΔS
UCR Spring Chinook																	
Wenatchee	4.37	1.03	1.11	1.02	1.08					1.10	1.49	1.00	1.01			1.00	1.00
UCR Steelhead																	
Methow	3.80	1.15	1.67	1.00	1.00					2.21	20.36	1.00	1.00				

This incremental change is calculated given alternative assumptions regarding effectiveness of hatchery-origin natural spawners, most recent years to include in base period, and modeling approach. Results are expressed both as a multiplier representing a change in annual population growth rate ($\Delta\lambda$) and a multiplier representing a change in per-generation survival (ΔS). $\Delta S = \Delta\lambda^{\text{Mean Generation Time}}$.

[1] Assumed for the Draft Biological Opinion. The next version of the NMFS Biological Opinion will use a better estimate of 5.04 for A-Run and 6.49 for B-Run.

Table C-3. Needed incremental change from base period survival to achieve 5% risk of extinction in 100 years.

		Hatchery Spawner Effectiveness = 20%								Hatchery Spawner Effectiveness = 80%							
		1980 to Most Recent				1980 to Projected 2004				1980 to Most Recent				1980 to Projected 2004			
ESU	Mean Gen. Time	CRI		QAR		CRI		QAR		CRI		QAR		CRI		QAR	
Population		$\Delta\lambda$	ΔS	$\Delta\lambda$	ΔS	$\Delta\lambda$	ΔS	$\Delta\lambda$	ΔS	$\Delta\lambda$	ΔS	$\Delta\lambda$	ΔS	$\Delta\lambda$	ΔS	$\Delta\lambda$	ΔS
Snake Spring/ Summer Chinook																	
Bear Valley	4.52	1.02	1.09			1.00	1.00			1.02	1.09			1.80	1.00		
Imnaha	4.56	1.24	2.67			1.18	2.09			1.77	13.51			1.67	10.37		
Johnson	4.52	1.00	1.00			1.00	1.00			1.00	1.00			1.00	1.00		
Marsh	4.54	1.08	1.42			1.03	1.12			1.08	1.42			1.03	1.12		
Minam	4.52	1.31	3.33			1.20	2.24			1.84	15.58			1.66	9.88		
Poverty	4.52	1.01	1.05			1.00	1.00			1.07	1.33			1.02	1.09		
Sulphur	4.50	1.15	1.84			1.08	1.41			1.15	1.84			1.08	1.41		
Snake Fall Chinook	4.12	1.16	1.84							1.53	5.70						
Snake Steelhead																	
A-Run	4.00[1]	1.84	11.34							4.29	337.14						
B-Run	4.00[1]	1.97	14.91							4.77	515.53						

		Hatchery Spawner Effectiveness = 20%								Hatchery Spawner Effectiveness = 80%							
		1980 to Most Recent				1980 to Projected 2004				1980 to Most Recent				1980 to Projected 2004			
ESU	Mean Gen. Time	CRI		QAR		CRI		QAR		CRI		QAR		CRI		QAR	
Population		$\Delta\lambda$	ΔS	$\Delta\lambda$	ΔS	$\Delta\lambda$	ΔS	$\Delta\lambda$	ΔS	$\Delta\lambda$	ΔS	$\Delta\lambda$	ΔS	$\Delta\lambda$	ΔS	$\Delta\lambda$	ΔS
UCR Spring Chinook																	
Wenatchee	4.37	1.23	2.43	1.14	1.75					1.30	3.15	1.13	1.70			1.08	1.40
UCR Steelhead																	
Methow	3.80	1.47	4.32	1.04	1.15[2]					2.81	50.37	1.22	2.15				

This incremental change is calculated given alternative assumptions regarding effectiveness of hatchery-origin natural spawners, most recent years to include in base period, and modeling approach. Results are expressed both as a multiplier representing a change in annual population growth rate ($\Delta\lambda$) and a multiplier representing a change in per-generation survival (ΔS). $\Delta S = \Delta\lambda^{\text{Mean Generation Time}}$.

[1] Assumed for the Draft Biological Opinion. The next version of the NMFS Biolocial Opinion will use a better estimate of 5.04 for A-Run and 6.49 for B-Run.
[2] This number was incorrectly reported as 2.15 in analyses supporting the Draft Biological Opinion.

Table C-4. Needed incremental change from base period survival to achieve 50% likelihood of recovery in 48 years.

		Hatchery Spawner Effectiveness = 20%								Hatchery Spawner Effectiveness = 80%							
		1980 to Most Recent				1980 to Projected 2004				1980 to Most Recent				1980 to Projected 2004			
ESU	Mean Gen. Time	CRI		QAR		CRI		QAR		CRI		QAR		CRI		QAR	
Population		$\Delta\lambda$	ΔS	$\Delta\lambda$	ΔS	$\Delta\lambda$	ΔS	$\Delta\lambda$	ΔS	$\Delta\lambda$	ΔS	$\Delta\lambda$	ΔS	$\Delta\lambda$	ΔS	$\Delta\lambda$	ΔS
Snake Spring/ Summer Chinook																	
Bear Valley	4.52	1.06	1.30			1.04	1.20			1.06	1.30			1.04	1.20		
Imnaha	4.56	1.32	3.51			1.24	2.70			1.68	10.52			1.64	9.54		
Johnson	4.52	1.03	1.15			1.00	1.00			1.03	1.15			1.00	1.00		
Marsh	4.54	1.13	1.77			1.09	1.48			1.13	1.77			1.09	1.48		
Minam	4.52	1.32	3.49			1.22	2.48			1.76	12.76			1.65	9.62		
Poverty	4.52	1.05	1.25			1.02	1.09			1.11	1.59			1.06	1.30		
Sulphur	4.50	1.10	1.53			1.08	1.41			1.10	1.53			1.08	1.41		
Snake Fall Chinook	4.12	1.25	2.54							1.64	7.63						
Snake Steelhead[3]																	
A-Run	4.00[1]																
B-Run	4.00[1]																

		Hatchery Spawner Effectiveness = 20%								Hatchery Spawner Effectiveness = 80%							
		1980 to Most Recent				1980 to Projected 2004				1980 to Most Recent				1980 to Projected 2004			
ESU	Mean Gen. Time	CRI		QAR		CRI		QAR		CRI		QAR		CRI		QAR	
Population		$\Delta\lambda$	ΔS	$\Delta\lambda$	ΔS	$\Delta\lambda$	ΔS	$\Delta\lambda$	ΔS	$\Delta\lambda$	ΔS	$\Delta\lambda$	ΔS	$\Delta\lambda$	ΔS	$\Delta\lambda$	ΔS
UCR Spring Chinook																	
Wenatchee	4.37	1.36	3.84	1.26	2.70					1.43	4.71	1.20[2]	2.20[2]			1.19	2.15
UCR Steelhead																	
Methow	3.80	1.67	7.09	1.12	1.55					3.12	75.31	1.35	3.10				

This incremental change is calculated given alternative assumptions regarding effectiveness of hatchery-origin natural spawners, most recent years to include in base period, and modeling approach. Results are expressed both as a multiplier representing a change in annual population growth rate ($\Delta\lambda$) and a multiplier representing a change in per-generation survival (ΔS). $\Delta S = \Delta\lambda^{\text{Mean Generation Time}}$.

[1] Assumed for the Draft Biological Opinion. Next version of the NMFS Biological Opinion will use a better estimate of 5.04 for A-Run and 6.49 for B-Run.
[2] This estimate was not available for the Draft Biological Opinion.
[3] Recovery level has not been proposed for this ESU.

Table C-5. Needed incremental change from base period survival to achieve 50% likelihood of recovery in 100 years.

		Hatchery Spawner Effectiveness = 20%								Hatchery Spawner Effectiveness = 80%							
		1980 to Most Recent				1980 to Projected 2004				1980 to Most Recent				1980 to Projected 2004			
ESU	Mean Gen. Time	CRI		QAR		CRI		QAR		CRI		QAR		CRI		QAR	
Population		$\Delta\lambda$	ΔS	$\Delta\lambda$	ΔS	$\Delta\lambda$	ΔS	$\Delta\lambda$	ΔS	$\Delta\lambda$	ΔS	$\Delta\lambda$	ΔS	$\Delta\lambda$	ΔS	$\Delta\lambda$	ΔS
Snake Spring/ Summer Chinook																	
Bear Valley	4.52	1.03	1.16			1.01	1.07			1.03	1.16			1.01	1.07		
Imnaha	4.56	1.29	3.16			1.21	2.43			1.64	9.47			1.61	8.77		
Johnson	4.52	1.02	1.08			0.99	0.94			1.02	1.08			0.99	0.94		
Marsh	4.54	1.09	1.50			1.05	1.26			1.09	1.50			1.05	1.26		
Minam	4.52	1.28	3.08			1.19	2.19			1.71	11.27			1.66	9.88		
Poverty	4.52	1.04	1.17			1.00	1.02			1.09	1.48			1.04	1.19		
Sulphur	4.50	1.06	1.30			1.04	1.20			1.06	1.30			1.04	1.20		
Snake Fall Chinook	4.12	1.22	2.29							1.60	6.87						
Snake Steelhead[3]																	
A-Run	4.00[1]																
B-Run	4.00[1]																

		Hatchery Spawner Effectiveness = 20%								Hatchery Spawner Effectiveness = 80%							
		1980 to Most Recent				1980 to Projected 2004				1980 to Most Recent				1980 to Projected 2004			
ESU	Mean Gen. Time	CRI		QAR		CRI		QAR		CRI		QAR		CRI		QAR	
Population		$\Delta\lambda$	ΔS	$\Delta\lambda$	ΔS	$\Delta\lambda$	ΔS	$\Delta\lambda$	ΔS	$\Delta\lambda$	ΔS	$\Delta\lambda$	ΔS	$\Delta\lambda$	ΔS	$\Delta\lambda$	ΔS
UCR Spring Chinook																	
Wenatchee	4.37	1.31	3.26	1.24	2.55					1.37	4.00	1.21[2]	2.30[2]			1.17	2.02
UCR Steelhead																	
Methow	3.80	1.62	6.29	1.12	1.55					3.02	66.77	1.34	3.00				

This incremental change is calculated given alternative assumptions regarding effectiveness of hatchery-origin natural spawners, most recent years to include in base period, and modeling approach. Results are expressed both as a multiplier representing a change in annual population growth rate ($\Delta\lambda$) and a multiplier representing a change in per-generation survival (ΔS). $\Delta S = \Delta\lambda^{\text{Mean Generation Time}}$.

[1] Assumed for the Draft Biological Opinion. The next version of the NMFS Biological Opinion will use a better estimate of 5.04 for A-Run and 6.49 B-Run.
[2] This estimate was not available for the Draft Biological Opinion.
[3] A recovery level has not been proposed for this ESU.

The QAR survival and recovery indicator metric estimates are from Cooney (2000) and various personal communications with T. Cooney (NMFS). QAR estimates applied only to UCR steelhead and UCR spring chinook. QAR estimates of needed survival change were sometimes reported only as changes in per-generation survival. To generate $\Delta\lambda$ in Tables C2 to C5 for QAR estimates, Equation 2 was rearranged as follows:

(3) $$\Delta\lambda = \Delta S^{(1/\text{Mean Generation Time})}$$

Methods used to generate the QAR estimates are described in Cooney (2000).

C.3.2.2 Key Assumptions Influencing Base Period Survival and Recovery Indicator Metric Estimates

NMFS considered three sets of alternative assumptions that influenced base period survival and recovery indicator metrics. The first is the **effectiveness of hatchery-origin natural spawners** for populations in which both wild- and hatchery-origin spawners contribute to production. In these mixed populations, the productivity of the wild-origin spawners is unknown. If the reproductive success of hatchery-origin spawners has been high during the base period, then the productivity of natural-origin spawners is lower than would be predicted from the mixed stock returns. In this situation, a large improvement in the survival of natural-origin fish may be necessary to reduce risk to the levels described in Table C-1. Conversely, if the effectiveness of hatchery-origin spawners has been low during the base period, productivity of natural-origin spawners is higher than in the previous case, and a smaller survival improvement is needed.

The effectiveness of hatchery-origin natural spawners during the base period could have ranged from 0% to 100%. Based on a review of pertinent literature, NMFS considers a range of between 20 to 80% effectiveness to capture a large fraction of realistic scenarios (Waples 2000). While it may be possible to further narrow this range if there is an understanding of the specific characteristics of the hatchery-produced spawners (e.g., locally derived, non-domesticated versus non-native or domesticated hatchery populations), NMFS applied the full range to all populations evaluated in the Draft Biological Opinion.

The second assumption that affects survival and recovery indicator metrics is the **selection of the base time period**. Extinction risk depends on the trend during the base period, variability in the trend, and current population level. Results for some populations can vary drastically, depending on choice of the starting year of the time series (Waples 1991). For this reason, and because of assumptions of the Dennis et al. (1991) extinction risk model regarding time series characteristics (McClure et al. 2000, their section IV.C), the relevant time period must be chosen carefully. NMFS considers the period between 1980 and the present the most appropriate for all ESUs considered in this biological opinion (Schiewe 2000). Because it most closely resembles current operation and configuration of the hydrosystem, including upstream storage. This includes the doubling of water storage capacity in the 1970s, which is likely to have affected the freshwater plume and estuarine conditions.

While NMFS did not consider alternative starting years in this analysis, it did consider alternative definitions of "the present" for two ESUs. For all ESUs, the primary analysis used the most recently available return year, which ranged from 1996 for SR fall chinook to 1999 for SR spring/summer chinook (McClure et al. 2000, Table C-1). For UCR spring chinook (Cooney 2000; T. Cooney pers. comm., July 2000) and SR spring/summer chinook (McClure et al. 2000, Table B-10, "High" category), NMFS also included preliminary 2000 return estimates, projected 2001 returns from 2000 jack counts, and 2002 to 2004 returns assumed equal to the updated 1980 to 2001 average. Because survival of fish returning in 2000 and projected to return in 2001 is higher than that occurring during most other years of the time series, addition of these return years results in a lower estimate of extinction risk and a lower needed change in survival.

The third factor influencing these results was **<u>use of CRI or QAR analysis</u>** for UCR steelhead and UCR spring chinook survival and recovery indicator metric estimates. QAR estimates of needed survival change are consistently lower than those of CRI for these ESUs. The differences between the two approaches are not great for UCR spring chinook, which have a relatively small contribution of hatchery-produced natural spawners, but the results are extremely different for UCR steelhead, which have a very high proportion of hatchery-origin natural spawners. NMFS does not understand the nature of these discrepancies at present and is working to resolve them. Until this occurs, NMFS includes both analytical approaches to represent a reasonable range of results for the UCR ESUs.

To summarize, the Draft Biological Opinion included two alternatives for each of three key assumptions influencing the range of results for the survival and recovery indicator metrics. Table C-6 displays each alternative and the ESUs to which it applies.

Table C-6. Alternative assumptions for base period survival and recovery indicator metrics.

Assumption	Alternatives Included	ESUs to Which Alternatives Were Applied
Effectiveness of Hatchery-Origin Natural Spawners During Base Period	1. 20%, relative to wild-origin natural spawners 2. 80%, relative to wild-origin natural spawners	All five ESUs included in the quantitative analysis.
Base Period (Years Included in Estimate of Annual Population Growth Rate and Per-Generation Survival Rate)	1. 1980 - most recent return year for which spawner counts are available 2. 1980 - projected 2004 spawner counts	First alternative applied to all five ESUs. Both alternatives are applied only to UCR spring chinook and SR spring/summer chinook.
Analytical Method	1. CRI 2. QAR	First alternative applied to all five ESUs. Both alternatives are applied only to UCR spring chinook and UCR steelhead.

C.3.2.3 Full Mitigation Indicator Metric

Annex 1 describes the method of estimating the natural survival rate through the FCRPS, for evaluation of the full mitigation indicator metric. The survival rate is expressed as (juvenile * adult) survival between the uppermost federal reservoir passed by a given ESU and the tailrace of Bonneville Dam. NMFS considered various approaches to generating estimates of juvenile and adult survival in Annex 1. For four of the five ESUs in the quantitative analysis, only the single approach that NMFS considered representative of the best available science was included in the Draft Biological Opinion. For SR fall chinook, NMFS considered two approaches to estimating juvenile survival through free-flowing river reaches equally valid and included each to represent the range of possible results. Table C-7 displays NMFS' best estimates of the natural survival rates associated with the full mitigation indicator metric.

Table C-7. Summary of estimates of life-stage-specific FCRPS hydrosystem survival for assessing the full mitigation indicator metric.

ESU	Life Stage: Spawning to Smolt	Life Stage: Smolt Survival from Upper to Lower Dam	Life Stage: 1 - Delayed Mortality of Smolts Below Lower Dam	Life Stage: Adult Survival from Lower to Upper Dam	Life Stage: 1 - Delayed Mortality of Adults Above Upper Dam	Total Hydrosystem Survival (Juvenile * Adults)
Chinook Salmon:						
SR s/s chinook	N/A	0.82	1.0	0.85	1.0	0.70
SR fall chinook	Q	0.32 (Meth A)	1.0	0.72	1.0	0.23 - 0.55
UCR spr chinook	N/A	0.90	1.0	0.92	1.0	0.83
LCR chinook	Q	0.99	1.0	0.98	1.0	0.97
UWR chinook	N/A	N/A	1.0	N/A	N/A	1.0
Steelhead:						
SR steelhead	N/A	0.84	1.0	0.85	1.0	0.71
UCR steelhead	N/A	0.91	1.0	0.92	1.0	0.84
MCR steelhead	N/A	0.91	1.0	0.92	1.0	0.84
UWR steelhead	N/A	N/A	1.0	N/A	N/A	1.0
LCR steelhead	N/A	0.99	1.0	0.98	1.0	0.97
SR Sockeye	N/A	??	1.0	0.85	1.0	??
CR Chum	Q	??	1.0	0.85	1.0	??

Notes: Unless otherwise noted, estimates are multiyear means.
Estimation methods and data sets are described in Annex 1.
N/A = not applicable to the ESU; ?? = information not available; Q = qualitative discussion in Draft Biological Opinion narrative.

C.3.3 Average Life-Stage Survival During the Base Period

NMFS estimated average base period survival rates for all life stages for four ESUs included in this analysis. These survival estimates, along with estimates of maturity rates and age-specific fecundity, were incorporated into Leslie matrices so that λ and per-generation survival rates could be estimated. For each of these species, details of the “base matrix” are described below.

It was impossible to estimate average base period survival for all life stages of SR steelhead in time for the Draft Biological Opinion, although this may be possible for the final version. Instead, only those survival rates that changed from the base period to the present, or that are expected to change in the future given a specified action, were identified. The change in these survival rates for a given action was then compared to the needed change identified by CRI, without use of a Leslie matrix.

C.3.3.1 Snake River Spring/Summer Chinook Base Matrices

NMFS developed base period matrices for seven SR spring/summer chinook index stocks. These base matrices represented modifications to the SR spring/summer chinook matrices developed by CRI. Because the CRI matrices are described in detail in Section VI.A of McClure et al. (2000), this appendix focuses on a description of the modifications NMFS applied.

The starting point was the March 20, 2000, spreadsheet entitled "S-S80-99newse.xls," which was prepared by M. Marvier of CRI and can be downloaded at the CRI web site: http://www.nwfsc.noaa.gov/cri/documents.htm. This spreadsheet is one of two versions of the SR spring/summer chinook matrices CRI prepared, and it represents the one in which the estuarine survival term is based on empirical information specific to this ESU. It incorporates an estimate of age-two survival in the estuary and ocean (*se*) that is fit to estimates of smolt-to-adult returns (SAR), age-three and onward ocean survival estimates, harvest rates, and estimates of juvenile and adult passage survival. The CRI spreadsheet includes one matrix for each of the seven index stocks.

Seven spreadsheets, one for each index stock, were used for analyses in the Draft Biological Opinion. These can be downloaded from the following web site: http://www.nwr.noaa.gov/1salmon/salmesa/fedrec.htm. These spreadsheets consist of multiple worksheets, with each worksheet labeled on a tab near the bottom of the screen. Each spreadsheet includes a worksheet labeled "<Name of Stock> Matrix," which contains the original CRI matrix with modifications highlighted in yellow. The initial changes were as follows.

a) The base-period, adult-passage survival estimate was based on radio-telemetry, rather than on dam passage conversion rates. This is consistent with the methods used to estimate effects of actions on adults in the Draft Biological Opinion. NMFS assumed that base-period, adult-passage survival was equal to current adult survival, given the relative stability of adult passage configuration and operation since 1980 and the use of survival estimates from the 1970s and 1980s in NMFS' estimate of current adult survival in the Draft Biological Opinion, Section 6.2. This modification resulted in a higher estimate of adult survival than the CRI matrix and a corresponding reduction in the estimate of egg-to-smolt survival (s_1) when the matrix was fit to the base period spawner returns.

b) The base period harvest rate was the average of 1983 through 1999 harvest rates, rather than 1980-through-1999 harvest rates. NMFS made this minor change because the 1980 brood year would not have been harvested until at least 1983.

c) The proportion of smolts transported and the in-river survival rate were changed from the 1980-to-1996 PATH average to the 1982-to-1996 PATH average. NMFS made this minor change because the 1980 brood year would not have migrated until 1982. Calculations are available on the worksheet labeled "Base Passage Input."

d) NMFS changed the estimate of s_e estuary and early ocean survival from the 1980-through-1992 migration year average to the 1982-through-1992 average, for the reasons described above. Again, this resulted in a very minor change. NMFS included average s_e through 1992 only because SAR estimates were available through the 1992 migration year only. Calculations are available on the worksheet labeled "s2 Input," which is derived from the original CRI spreadsheet (SARmmm.xls), with changes highlighted in yellow.

Once these changes were made, the missing life stage (in this case, egg-to-smolt survival, s_1) was recalculated using the Euler equation, and the equilibrium annual rate of population growth was recalculated. Because the survival terms were fit to the median recruit-per-spawner observations during the base period, the estimate of λ was identical to that in the original CRI matrix. As described above, however, the back-calculated, egg-to-smolt survival was lower because adult survival was higher than in the original CRI matrix.

e) After s_1 was calculated, the CRI matrix was further changed to account for estimates and hypotheses regarding delayed mortality that may be caused by the hydrosystem. This involved further partitioning the age-two survival term. The CRI matrix partitioned the age-two survival s_2 term according to Equation 4:

(4) $s_2 = [((1\text{-}p_t) * s_d) + (p_t * s_b)] * s_e$

In this equation, p_t is the proportion of fish arriving at Lower Granite pool that is eventually placed on barges; s_b is the survival of fish on barges until release; s_d is the in-river survival of all other fish, including those that are destined for transport but die before barge loading; and s_e is post-Bonneville survival through the end of age-two, as described above.

NMFS further partitioned s_2 to account for estimates of differential post-Bonneville survival of transported fish compared to non-transported fish (*D*) and a range of assumptions regarding FCRPS-caused, post-Bonneville mortality of non-transported fish (λ_n of PATH; due to confusion with the term used to represent annual rate of population growth, "*EM*" is used).

(5) $s_2 = [((1\text{-}p_t) * s_d) + (p_t * s_b * D)] * (1\text{-}EM) * \text{"Non-Hydro } s_e\text{"}$

in which

(6) $\text{"Non-Hydro } s_e\text{"} = (1\text{- post-Bonneville mortality not attributed to the FCRPS})$
$= s_2 \div [(((1\text{-}p_t) * s_d) + (p_t * s_b * D))\text{*} (1\text{-}EM)]$

(7) $\text{"Hydro } s_e\text{"} = (1 \text{ - post-Bonneville mortality attributed to FCRPS})$
$= [(((1\text{-}p_t) * s_d) + (p_t * s_b * D))\text{*} (1\text{-}EM)] \div [((1\text{-}p_t) * s_d) + (p_t * s_b)]$

(8) $s_e = \text{"Hydro } s_e\text{"} * \text{"Non-Hydro } s_e\text{"}$

In both the CRI matrix and the base matrix used for Draft Biological Opinion analyses, the direct passage survival terms were averages from PATH (Marmorek et al. 1998; data files in allpmrun.zip, obtained from C. Peters June 18, 1999). NMFS used the PATH retrospective results for a set of passage assumptions considered closest to mean PATH results (C. Peters, ESSA, pers. comm., June 1999) and averaged the estimates from the two alternative PATH passage models (FLUSH and CRiSP). Details are included in the worksheet labeled "Base Passage Input" in each spreadsheet. NMFS translated PATH output variables to variables subsequently used in this analysis according to the following transformation:

Barge or truck survival:

(9) $s_b = 0.98$

Proportion of LGR reservoir arrivals eventually transported:

(10) p_t = ([PATH "Pbt"]*exp(-[PATH "M"]))/s_b

In-river survival (including fish destined for transportation):

(11) s_d = [exp(-[PATH "M"]- (p_t * s_b))]/(1- p_t)

Total direct transport + inriver survival:

(12) $[((1-p_t) * s_d) + (p_t * s_b)]$ = exp(-[PATH "M"])

In Equations 10 through 12, PATH "M" is the absolute value of the natural log of total direct mortality of juveniles through the hydrosystem. PATH "Pbt" is the proportion of juveniles alive below Bonneville Dam that arrived via transportation.

NMFS estimated 1994 to 1997 average *D* for SR spring/summer chinook equal to 0.63 to 0.73 (NMFS 2000b; Section 6.2.3.3.1 of Draft Biological Opinion). NMFS assumed that this estimate also applies to the base period because there is empirical evidence to the contrary (Section 6.2.3.3.1 of Draft Biological Opinion). NMFS has not estimated *EM*, but assumes that it could range from zero to the highest rate estimated by PATH (Marmorek et al. 1998). The highest PATH estimate that corresponds to *D*=0.63 is *EM*=0.709, and the highest PATH estimate that corresponds to *D*=0.73 is *EM*=0.743. By highest PATH estimate, NMFS means an estimate that assumes that the hydrosystem is responsible for all extra mortality (Marmorek et al. 1998) that cannot be explained by PATH's productivity functions, estimates of year-to-year changes in productivity common to several stocks, and estimates of direct survival.

PATH did not actually estimate *EM* that corresponds to NMFS' *D* estimates. The *EM* estimates were derived from PATH total mortality estimates according to the following equation:

(13) *EM* = 1 - {[exp-(PATH "m"- PATH "M")] ÷ [(*D* * PATH "Pbt") + (1- PATH "Pbt")]}

in which PATH "m" is the absolute value of the natural logarithm of total mortality that cannot be explained by PATH's productivity functions or assessment of common changes in annual productivity. PATH "M" and PATH "Pbt" are as defined for Equations 10 through 12. NMFS applied PATH's average FLUSH and CRiSP passage model estimates for these terms and solved for *EM* using NMFS' estimates of *D*. Details are included in the worksheet labeled "Delayed Mort." on each spreadsheet. H. Schaller (USFWS) originally suggested this approach and applied it in his April 17, 2000, spreadsheet "lambdan.xls," which NMFS modified for this analysis.

The result is four combinations of *D* and *EM*, which NMFS evaluated for both the base period and for the actions that were compared to base period estimates (Table C-8).

Table C-8. Delayed mortality assumptions included in the SR spring/summer chinook analysis.

Assumption		Treatment in Draft Biological Opinion
D	***EM***	
0.63	0	Both $EM = 0$ estimates averaged together for "High Estimate" of direct and indirect juvenile survival through FCRPS.
0.73	0	
0.63	0.709	Both $EM > 0$ estimates averaged together for "Low Estimate" of direct and indirect juvenile survival through FCRPS.
0.73	0.743	

Note: This table includes the method of summarizing the four delayed mortality combinations in the Draft Biological Opinion.

The combinations of *D* and *EM* define the labels of four worksheets that contain base matrices arranged in columns for each delayed mortality assumption. The base matrices are in the third column (C) of each spreadsheet (reproduced as Tables C-A2-1 to C-A2-28 in Annex 2) and differ from each other only in these two input parameters and in the "*Hydro* s_e" and "*Non-Hydro* s_e" terms (inadvertently labeled "natural s_e" in the spreadsheets) that are estimated from the other terms. When *D* is low and *EM* is high, "*Hydro* s_e" is low and "*Non-Hydro* s_e" is high. When *D* is high and *EM* is low, the opposite is true. Once "*Non-Hydro* s_e" was determined for the base matrix, it was held constant in all action matrices. However, "*Hydro* s_e" was allowed to vary in response to different proportions of transported and non-transported fish (which modified the effects of a given *D* and *EM*) and to accommodate one assumption related to breaching, which hypothesized that any FCRPS-related post-Bonneville mortality would be eliminated if four of the eight FCRPS dams were breached.

In the Draft Biological Opinion, the survival rates associated with the two *D* estimates were averaged. Because the estimates were similar, there was no major biological issue defining the difference between the two estimates. This greatly reduced the number of assumption sets that had to be considered separately in the Draft Biological Opinion. Similarly, the two PATH-derived estimates of *EM* were averaged because the only factor defining their difference was the associated *D* estimate. The two resulting cases that were considered in the Draft Biological Opinion are described in Table C-8.

The estimates of direct and indirect juvenile and adult survival that were used to derive the base full mitigation indicator metric are described in the row labeled "Hydrosystem Juv * Adult" in the base spreadsheets (reproduced as Tables C-A2-1 to C-A2-28 in Annex 2). These estimates varied with the *D* estimates and *EM* assumptions.

C.3.3.2 Snake River Fall Chinook Base Matrices

The starting point for the SR fall chinook base matrices was the CRI fall chinook matrix described in Section VI.B of McClure et al. (2000), which was implemented in M. Marvier's spreadsheet "11-22-99fachlm.xls." NMFS modified the CRI matrix and prepared a new spreadsheet (Fall_July27DraftBiop.xls) for analyses in the Draft Biological Opinion. This new spreadsheet can be downloaded from the following web site: http://www.nwr.noaa.gov/1salmon/salmesa/fedrec.htm. It includes a worksheet labeled "Fall Chinook Base," which contains the original CRI matrix with modifications highlighted in yellow. McClure et al. (2000) documents the CRI matrix, so only the modifications to that matrix are detailed in this section. These modifications include the following:

a) The base period adult passage survival estimate was based on radio-telemetry, rather than on dam passage conversion rates. This is consistent with the methods used to estimate effects of actions on adults in the Draft Biological Opinion. NMFS assumed that base period adult survival was equal to current adult survival, given the relative stability of adult passage configuration and operation since 1980 and the use of survival estimates from the 1970s and 1980s in NMFS' estimate of current adult survival in the Draft Biological Opinion, Section 6.2. This modification resulted in a higher estimate of adult survival than the CRI matrix.

b) The base period in-river harvest rate was the average of 1982-through-1999 harvest rates, rather than 1993-through-1996 harvest rates in the CRI matrix. NMFS made this change to reflect the harvest rates that influenced survival of the 1980-through-1991 brood cycles (to which the s_1 term was fit). This resulted in a higher harvest mortality of adults than in the CRI matrix.

c) NMFS used the 1985-through-1996 age-specific ocean harvest rates, rather than the 1993-through-1996 ocean harvest rates used in the CRI matrix.. Again, the reason was to match the brood cycles to which the s_1 term was fit. Ideally, this would have included the 1982-through-1984 ocean harvest rates, but these were not available from Table 4.5-2 of Peters et al. (1999), which was the source of both the CRI and NMFS harvest rate estimates.

Once these changes were made, the missing life stage (in this case, first-year survival, s_1) was recalculated using the Euler equation, and the equilibrium annual rate of population growth was recalculated. Because the survival terms were fit to the median recruit-per-spawner observations during the base period, the estimate of λ was identical to that in the original CRI matrix. Because of the harvest rate and adult passage survival changes, however, the back-calculated, first-year survival rate s_1 was slightly higher than in the original CRI matrix, while the s_2 - s_6 survival rates were lower.

d) After s_1 was calculated, the CRI matrix was further changed to account for estimates and hypotheses regarding direct juvenile passage survival and delayed mortality that may be caused by the hydrosystem. This involved partitioning the age-one survival term, s_1. The CRI matrix included all phases of first-year survival (egg-to-smolt, juvenile passage through the hydrosystem, and estuary and ocean entry survival) in the s_1 term. NMFS partitioned this term as follows:

(14) $s_1 = [((1\text{-}p_t) * s_d) + (p_t * s_b * D)] * (1\text{-}EM) * \text{“Non-Hydro } s_1\text{”}$

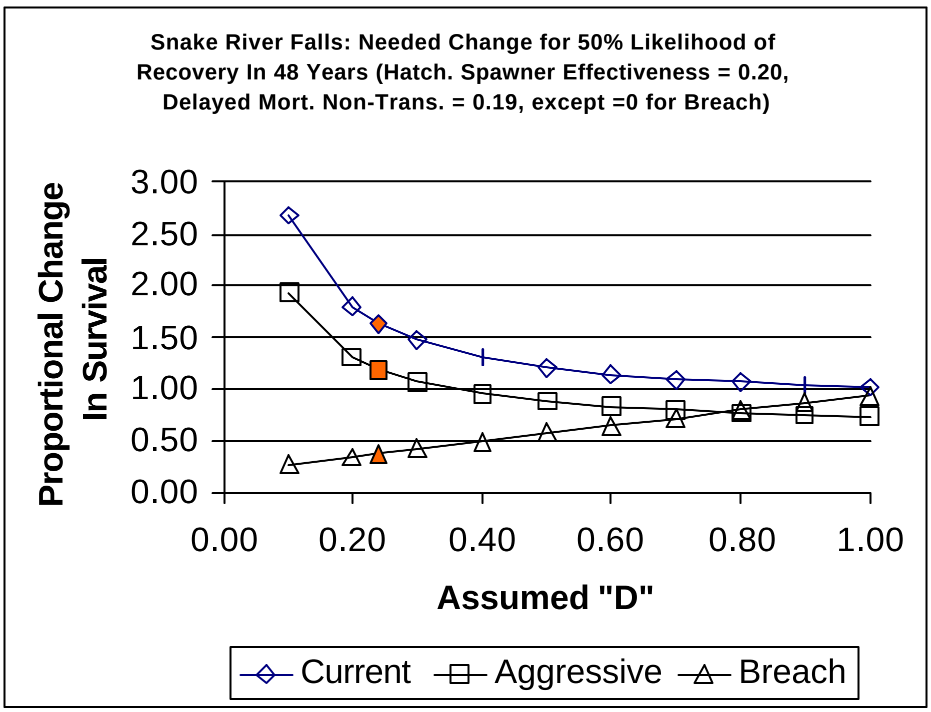
In this equation, p_t, s_b, s_d, D, and EM are as defined for SR spring/summer chinook in Section C.3.3.1. "*Non-Hydro* s_1" includes egg-to-smolt survival and that component of below-Bonneville first year survival that is not influenced by passage through the hydrosystem. That is, "*Non-Hydro* s_1" is *(1 - mortality not attributed to the FCRPS)*.

In the base matrix used for Draft Biological Opinion analyses, the direct passage survival terms were averages from PATH (Peters et al.1999; data files in newfall.zip, obtained from C. Peters, October 5, 1999). NMFS used the PATH "retrospective" results for a set of passage assumptions considered closest to mean PATH results (C. Peters, ESSA, pers. comm., October 1999) and averaged the estimates from the two alternative PATH passage models (FLUSH and CRiSP). Details are included in the worksheet labeled "Passage Base" in each spreadsheet. PATH variables were translated into matrix terms according to Equations 9 through 12. For SR fall chinook, however, an additional modification of the base period PATH results was required. PATH did not include survival through Lower Granite reservoir in its SR fall chinook passage estimates because of difficulties distinguishing among mortality of actively migrating smolts and mortality of juveniles that are rearing in the reservoir before active migration. NMFS applied the current estimate of Lower Granite reservoir survival from SIMPAS modeling results (Draft Biological Opinion Section 6.2 and Appendix B) to adjust survival to the full reach. The resulting estimates represent a combination of rearing and passage mortality in Lower Granite reservoir. Details are included in the worksheet "Passage Base."

NMFS has not estimated *D* or *EM* for SR fall chinook salmon. As described in Section 6.2.3.3 of the Draft Biological Opinion, there is great uncertainty regarding differential post-Bonneville survival of this ESU. Because this species has not been the subject of formal transportation studies, the scientific justification for any given estimate of *D* is weaker than for SR spring/summer chinook salmon or steelhead. NMFS (2000b) reviewed the range of alternative assumptions used by Peters et al. (1999) to estimate *D* for this species: application of returns of transported and non-transported fish PIT-tagged during the 1995 outmigration, application of transport studies from McNary Dam (i.e., based on Hanford Reach fall chinook) to Snake River fall chinook, and comparisons of different assumptions about *D* and other values in relation to the best fit of a life-cycle model to the observed recruit-per-spawner data**.** The estimates of *D* derived using these alternative methods ranged from approximately 0.05 to more than 1.0. NMFS (2000b) reviewed these methods and noted that each had inherent strengths and weaknesses. For purposes of the Draft Biological Opinion, NMFS considered the PATH PIT-tag method more consistent with methods it used to estimate spring/summer chinook and steelhead *D*s than either of the other PATH approaches. Using this method, PATH estimated D=0.24, with very wide statistical confidence limits. NMFS concluded that this represents the best SR fall chinook *D*-estimate currently available and applied it as a point estimate in the fall chinook matrices.

Because this *D* estimate should be viewed with caution, NMFS conducted a sensitivity analysis our a wide range of possible *D*-values. Figure C-2 displays representative results of this analysis. Details are included in the worksheet labeled "D Sensitivity" in the fall chinook spreadsheet. These details include analyses for each survival and recovery indicator metric and for alternative *EM* assumptions. Figure C-2 displays the proportional changes in survival that are needed to meet the recovery indicator metric risk level in Table C-1 after implementing different actions. These results vary according to a range of *D* values displayed on the horizontal axis. Results for "current" and "aggressive" actions best show the sensitivity to alternative *D* assumptions, since those actions include transportation, whereas breaching does not. The sensitivity is greatest for *D* estimates less than about 0.40. If a higher *D* is assumed, results are fairly constant (i.e., the line becomes nearly horizontal). Because the assumption of D=0.24 is in the area of great sensitivity to alternative assumptions regarding *D*, the results should be interpreted with caution.

Figure C-2. Example of sensitivity of Snake River fall chinook results to alternative assumptions about differential post-Bonneville survival of transported smolts (*D*).



Note: Solid markers represent the assumed *D*=0.24, which was applied in this analysis. “Current” is the proposed action, “aggressive” represents the RPA, and “breach” represents four-dam Snake River breach.

NMFS applied the same approach to estimating a range of possible SR fall chinook *EM* values, as was used for SR spring/summer chinook. The low end of the range assumed that *EM* = 0, while the high end assumed the highest estimate of PATH (Peters et al. 1999). The highest PATH estimate that corresponds to *D*=0.24 is approximately *EM*=0.19. PATH did not actually estimate *EM* that corresponds to NMFS' *D* estimate. The *EM* estimate was derived from a PATH estimate of the "STEP" term in the fall chinook model that corresponded to *D* = 0.20. This was the closest approximation of *D* = 0.24 available at the time of the Draft Biological Opinion. The "STEP" term corresponds to the absolute value of the natural logarithm of non-transport "extra mortality" estimated by PATH (Peters et al. 1999). For fall chinook, Equation 15 was relevant.

(15) $EM = 1 - \exp(-\text{PATH "STEP"})$

Equation 15 was suggested by C. Peters (ESSA), and he provided the relevant PATH "STEP" results in a June 13, 2000, spreadsheet "fallsteps.xls." The worksheet labeled "Delayed Mort." in the Draft Biological Opinion fall chinook spreadsheet is a slight modification of Peters' spreadsheet.

The result is two combinations of *D* and *EM*, which NMFS evaluated for both the base period and for the actions that were compared to base period estimates (Table C-8).

Table C-9. Two combinations of delayed mortality assumptions included in the SR fall chinook analysis.

Assumption		Treatment in Draft Biological Opinion
D	***EM***	
0.24	0	High estimate of direct and indirect juvenile survival through FCRPS
0.24	0.19	Low estimate of direct and indirect juvenile survival through FCRPS

Note: This table presents the method of summarizing these combinations in the Draft Biological Opinion.

The combinations of *D* and *EM* define the labels of two worksheets that contain base matrices arranged in columns for each delayed mortality assumption. The base matrices are in the third column (C) of each spreadsheet (reproduced as Tables C-A2-29 to C-A2-30 in Annex 2). They differ from each other only in these two input parameters and in the "*Non-Hydro* s_1" term. Once "*Non-Hydro* s_1" was determined for the base matrix, it was held constant in all action matrices. However, the other s_1 survival terms were allowed to vary in the action matrices.

The estimates of direct and indirect juvenile and adult survival that were used to derive the full mitigation indicator metric are described in the row labeled "Hydrosystem Juv * Adult" in the base spreadsheets (reproduced as Tables C-A2-29 to C-A2-30 in Annex 2). These passage survival estimates varied with the *D* estimates and *EM* assumptions.

C.3.3.3 Upper Columbia River Spring Chinook Base Matrices

The starting point for the UCR spring chinook analysis was the Wenatchee River matrix (Wenmatrix.xls, April 6, 2000) developed by T. Cooney for the QAR process. The Wenatchee River population was evaluated because, of the three populations identified for this ESU, it is the one requiring the greatest change in survival to meet the criteria described in Table C-1 (see discussion in Section 6.3.2.1 of the Draft Biological Opinion). NMFS modified the QAR matrix and prepared a new spreadsheet (Wenatchee_CH_July27DraftBiop.xls) for analyses in the draft Biological Opinion. This new spreadsheet can be downloaded from the following web site: http://www.nwr.noaa.gov/1salmon/salmesa/fedrec.htm. It includes a worksheet labeled "Cooney QAR Base Matrix," which contains the original QAR matrix with changes highlighted in yellow. Because Cooney (2000) documents the QAR matrix, only the modifications to that matrix are detailed in this section. These modifications include the following:

a) The base-period, adult-passage survival estimate was based on radio-telemetry, rather than on dam passage conversion rates. This is consistent with the methods used to estimate effects of actions on adults in the Draft Biological Opinion. NMFS assumed that base-period, adult-survival was equal to current adult survival, given the relative stability of adult passage configuration and operation since 1980 and the use of survival estimates from the 1970s and 1980s in NMFS' estimate of current adult survival in the Draft Biological Opinion, Section 6.2. This modification increased adult survival from the QAR estimate.

b) NMFS added a pre-spawning mortality estimate of 10% (Beamesderfer et al. 1998). This reduced adult survival from the QAR estimate.

c) The base-period, in-river harvest rate was the average of 1983-through-1998 harvest rates, rather than 1983-through-1995 harvest rates in the QAR matrix. We made this change to reflect the harvest rates that influenced survival of the 1980-through-1994 brood cycles (to which the s_2 term was fit). This resulted in a higher harvest mortality of adults than in the QAR matrix.

d) NMFS partitioned juvenile survival (s_2) and adult mortality (μ) in a manner slightly different from that in the QAR matrix. The main differences were a more explicit differentiation between FCRPS hydrosystem effects and those associated with passage through three public utility district (PUD) dams and incorporation of a term to represent possible FCRPS-related delayed mortality of non-transported fish. The third difference was the merging of two QAR terms that apply to survival below Bonneville that is unaffected by hydrosystem passage. Cooney (2000) partitioned this into a term representing transition from the river to estuary (*Ser*) and another term representing survival from post-estuarine entry through early ocean residence (*Seo*), while NMFS combined these into the "*Non-Hydro* s_e" term. This partitioning in the QAR matrix was done to investigate potential effects of bird predation, which was beyond the scope of the present analysis.

To expand on the third point, the QAR matrix partitioned second-year survival as the following:

(16) $s_2 = Sp * Ser * (1\text{-}p_t + D * p_t) * Seo$

in which *Ser* and *Seo* were as defined above, *Sp* is direct passage survival of transported and non-transported fish from Rock Island Dam to Bonneville Dam, and p_t is the proportion of fish arriving at McNary Dam that are transported. The modification was as follows:

(17) $$s_2 = s_{d\text{-}PUD} * [((1\text{-}p_t) * s_d) + (p_t * s_b * D)] * (1\text{-}EM) * \text{“}Non\text{-}Hydro\ s_e\text{”}$$

In this equation, $s_{d\text{-}PUD}$ represents survival from Rock Island Dam to the head of McNary pool. All other terms are as defined previously, except that they apply to the river reach below the head of McNary pool. NMFS also partitioned adult survival through the FCRPS from adult survival through PUD projects.

Once the adult survival changes were made, the missing life stage (in this case, total second-year survival, s_2) was recalculated using the “Cooney QAR Base Matrix” worksheet. The equilibrium annual rate of population growth was then recalculated. Because the survival terms were fit to the recruitment observations during the base period, the estimate of λ was identical to that in the original QAR matrix. Because the increased adult passage survival and addition of pre-spawning mortality essentially cancelled each other, the back-calculated, second-year survival rate s_2 was also nearly identical to that in the original QAR matrix.

NMFS used QAR estimates for all base-period juvenile, direct-passage survival rates. It also used the estimate of $D = 1.0$ from the QAR analysis, which is based on NMFS transportation studies conducted at McNary dam during the base period. Cooney (2000) did not estimate *EM* for this population. As described in Section 6.2.3.3 of the Draft Biological Opinion, NMFS considers possible values of *EM* to range from zero to the highest PATH estimate for SR spring/summer chinook (Section C.3.3.1). Table C-10 describes the resulting range of assumptions.

Table C-10. Two combinations of delayed mortality assumptions included in the UCR spring chinook analysis.

Assumption		**Treatment in Draft Biological Opinion**
D	***EM***	
1.0	0	High estimate of direct and indirect juvenile survival through FCRPS
1.0	0.709	Averaged together for Low estimate of direct and indirect juvenile survival through FCRPS
1.0	0.743	

Note: This table presents the method of summarizing these combinations in the Draft Biological Opinion.

The combinations of *D* and *EM* define the labels of three worksheets that contain base matrices arranged in columns for each delayed mortality assumption. The base matrices are in the third column (C) of each spreadsheet (reproduced as Tables C-A2-31 to C-A2-33 in Annex 2) and differ from each other only in these two input parameters and in the “*Non-Hydro* s_e” term. Once “*Non-Hydro* s_e” was determined for the base matrix, it was held constant in all action matrices. However, the other s_2 survival terms were allowed to vary in the action matrices.

The estimates of direct and indirect juvenile and adult survival that were used to derive the base full mitigation indicator metric are described in the row labeled "FCRPS Hydrosystem Juv * Adult" in the base spreadsheets (reproduced as Tables C-A2-31 to C-A2-33 in Annex 2). These passage survival estimates varied with the *D* estimates and *EM* assumptions.

C.3.3.4 Upper Columbia River Steelhead Base Matrices

The starting point for the UCR steelhead analysis was the Methow River matrix (sthdmatrix.xls, June 21, 2000) developed by T. Cooney for the QAR process. The Methow River population was evaluated because, of the three populations identified for this ESU, it requires the greatest change in survival to meet the criteria described in Table C-1 (see discussion in Section 6.3.2.1 of the Draft Biological Opinion). Cooney (2000) documents an earlier version of the QAR matrix. Most of the changes in the June 21 QAR matrix were identical to those described in points (a) through (d) for UCR spring chinook (Section C.3.3.3).

NMFS slightly modified the QAR base matrix and prepared a new spreadsheet (Methow_SH_July27DraftBiop.xls) for analyses in the draft Biological Opinion. This new spreadsheet can be downloaded from: http://www.nwr.noaa.gov/1salmon/salmesa/fedrec.htm. The primary modification was the inclusion of alternative estimates of *EM*. Cooney (2000) did not estimate *EM* for this population and implicitly assumed that it was zero. As described in Section 6.2.3.3 of the Draft Biological Opinion, NMFS considers possible values of *EM* to range from zero to the highest PATH estimate for SR spring/summer chinook (Section C.3.3.1). NMFS also used the estimate of $D = 1.0$ from the QAR analysis, which is based upon transportation studies NMFS conducted at McNary dam during the base period. Table C-11 describes the resulting range of assumptions.

Table C-11. Two combinations of delayed mortality assumptions included in the UCR steelhead chinook analysis.

Assumption		Treatment in Draft Biological Opinion
D	***EM***	
1.0	0	High estimate of direct and indirect juvenile survival through FCRPS
1.0	0.709	Averaged together for Low estimate of direct and indirect juvenile survival through FCRPS
1.0	0.743	

Note: This table presents the method of summarizing these combinations in the Draft Biological Opinion.

The estimate of *EM* defines the labels of worksheets that contain base matrices arranged in columns for each delayed mortality assumption. The base matrices also vary according to assumptions regarding effectiveness of hatchery-produced natural spawners during the base period. NMFS used the estimates for 25 and 75% hatchery spawner effectiveness, which approximate the 20 to 80% range NMFS considered most likely (Waples 2000). The base matrices it used are in the third and fifth columns (C and E) of each spreadsheet (reproduced as Tables C-A2-34 to C-A2-39 in Annex 2). Once "*Non-Hydro* s_e" (inadvertantly labeled "Natural *se*" in the spreadsheet) was determined for the base matrix, it was held constant in all action matrices. The other s_2 survival terms were, however, allowed to vary in the action matrices.

The estimates of direct and indirect juvenile and adult survival that were used to derive the base full mitigation indicator metric are described in the rows labeled "direct_ind_FCRPS" and "Conv. Rte FCRPS" in the base spreadsheets (reproduced as Tables C-A2-34 to C-A2-39 in Annex 2). The juvenile passage survival estimates varied with the *EM* assumptions.

C.3.3.5 Snake River Steelhead Base Incremental Analysis

As described in Section 6.3.4 of the Draft Biological Opinion, NMFS did not construct a Leslie matrix for SR steelhead. Instead, it conducted a simple incremental analysis and applied results to aggregate A-Run and aggregate B-Run SR steelhead. This analysis simply estimates expected proportional changes in average survival from the base period (1980 brood year through approximately 1992 brood year [1997 returns]) to the survival rates expected from other actions, without attempting to estimate survival rates through the entire life cycle. The analysis focuses only on those life-stage survival rates likely to have changed from base to current conditions or likely to further change through implementation of the RPA. A spreadsheet titled "SR_stlhd_July27DraftBiop.xls" contains details and can be downloaded from the following web site:
http://www.nwr.noaa.gov/1salmon/salmesa/fedrec.htm.

Three survival rates have either changed from the average 1980-to-1992 brood year survivals to the present, or are expected to change as a result of other actions. These are in-river harvest rates, juvenile survival through the FCRPS, and adult survival through the FCRPS.

For A-Run steelhead, the 1984-to-1998 average harvest rate was 13.7%, while the corresponding rate for B-Run steelhead was 25.9%. The source of these estimates is a report to the Technical Advisory Committee (TAC) of *U.S. v. Oregon* (Beamesderfer 2000; Table C-12). The relevant survival rates (1 - harvest rate) are 86.3% for A-Run steelhead and 74.1% for B-Run steelhead.

Juvenile passage survival during the base period is unknown, but probably was lower, on average, than current survival. Neither PATH nor NMFS attempted to estimate the base period SR steelhead transported and non-transported juvenile survival rates. Because direct estimates of historical steelhead juvenile passage survival are not available, NMFS assumed that the proportional change in juvenile SR steelhead survival from the base to current (proposed action) condition equals the proportional change estimated for SR spring/summer chinook salmon (19%; 1.19 survival multiplier; see Section C.3.4.1). Improvements to the system over that period (e.g., new bypasses, increased spill levels, increased flow rates, and new transportation facilities) have probably affected spring-migrating yearling steelhead and yearling chinook in a similar manner. The 1998 FCRPS Biological Opinion contains details regarding similar effects of the hydrosystem on the two ESUs. The 1998 FCRPS Biological Opinion relied on a comparison of SR spring/summer chinook and SR steelhead to draw conclusions for steelhead.

Table C-12. Harvest rates on wild Snake River steelhead (Beamesderfer 2000).

Run Year	Wild "A" Harvest Rate	Wild "B" Harvest Rate
1984	0.120	0.366
1985	0.207	0.310
1986	0.138	0.267
1987	0.157	0.372
1988	0.171	0.234
1989	0.159	0.350
1990	0.160	0.215
1991	0.146	0.300
1992	0.162	0.263
1993	0.152	0.191
1994	0.103	0.186
1995	0.104	0.186
1996	0.089	0.346
1997	0.104	0.143
1998	0.088	0.156
1999		
2000		
84-98 Mean	**0.137**	**0.259**
93-98 Mean	**0.107**	**0.201**
survival change	**1.036**	**1.078**

The resulting base period juvenile survival estimates are 0.391 for high assumptions and 0.107 for low assumptions ("Summary-A" and "Summary-B" worksheets). Each estimate represents the proposed action survival estimate, divided by 1.19. Both the high and low estimates represent an average of NMFS' (2000b) 0.52-to-0.58 range of differential post-Bonneville survival (D) estimates for this ESU. The high and low juvenile passage survival estimates differed only in the treatment of delayed mortality of non-transported fish. Under the low delayed mortality assumption, no post-Bonneville mortality of non-transported fish was attributed to the hydrosystem. Under the high delayed mortality assumption, post-Bonneville mortality attributed to the hydrosystem was assumed to be no higher than that estimated for SR spring/summer chinook salmon (0.709 to 0.743).

Adult passage survival for the base period was estimated as 79.6% ("Summary-A" and "Summary-B" worksheets). NMFS assumed that base period adult survival was equal to current adult survival, given the relative stability of adult passage configuration and operation since 1980 and the use of survival estimates from the 1970s and 1980s in NMFS' estimation of current adult survival in the Draft Biological Opinion, Section 6.2.

For the incremental analysis, NMFS multiplied the three life-stage survivals described above to obtain a survival rate that could be compared to a similar rate representing alternative actions for evaluating survival and recovery metrics. When only the passage survival rates were considered, the full mitigation metric could be evaluated.

C.3.4 Proportional Survival Change Associated With Proposed Action

NMFS updated survival rates included in the base matrices to reflect the expected effects of the proposed action and actual and anticipated changes in any other life stage survival rates from the average, base-period survival rates NMFS evaluated. Effects of the proposed action and described them in Section 6.2 of the Draft Biological Opinion. SIMPAS model analyses quantified expected effects on juveniles. The All-H paper (NMFS 2000a) guided expectations for survival changes in other life stages. NMFS could not quantify the possible changes in survival resulting from habitat-related actions, but did include expectations regarding harvest and implementation of the Mid-Columbia HCP.

C.3.4.1 Juvenile and Adult Hydrosystem Survival Changes

SIMPAS passage model analyses quantified expected changes in direct juvenile passage survival (Appendix B; Section 6.2 of the Draft Biological Opinion). Results of these analyses are in worksheets labeled "NewPassageInput" in the SR spring/summer chinook and UCR Wenatchee spring chinook spreadsheets. Similar worksheets are labeled "Passage New" for SR fall chinook and "FCRPS Juvs" for UCR Methow steelhead. For SR steelhead, SIMPAS results are combined with *D* estimates and *EM* assumptions in worksheets labeled "Passage, EM=0," "Passage, EM=0.709," and "Passage, EM=0.743." The proposed action is described as "Current" in all spreadsheets. The expected survival changes apply to the Lower Granite pool to Bonneville Dam reach for Snake River ESUs and the McNary pool to Bonneville Dam reach for UCR ESUs. Survival of UCR ESUs was assumed equal to the survival of SR ESUs of the same species through the four lower Columbia River projects. Estimates of *D* and assumptions regarding *EM* were identical to those applied to the base period FCRPS juvenile survival estimates. SIMPAS results were estimated for a range of water years (WY): 1994-through-1999 WY for SR spring/summer chinook and SR steelhead; 1995-through-1999 WY for SR fall chinook. Results from all WY were averaged in analyses because the future is likely to be an unknown mixture of these conditions.

As described in Sections C.3.3.1 through C.3.3.5, adult passage survival expected under the proposed action was assumed to be identical to that occurring in the base period.

C.3.4.2 Changes In Harvest Rates

Average harvest rates changed from the base period to the present for SR fall chinook and SR steelhead. The All-H Paper (NMFS 2000a) indicates that recent harvest rates are expected to continue in the future.

NMFS characterized recent SR steelhead in-river harvest rates as the average of 1993-through-1998 wild harvest rates. The *U.S.* v. *Oregon* TAC prepared estimates for these years, which are presented in Table C-12.

NMFS characterized recent SR fall chinook ocean harvest rates as the 1993-through-1996, age-specific average harvest rates. These estimates were obtained from Table 4.5-2 of Peters et al. (1999). When the age-specific harvest rates (h_2 - h_6) were incorporated into the matrix, the proportion of fish harvested in each year and the cumulative proportion harvested over all years in the ocean were functions of the assumed natural survival rate (s_o = 0.8/yr; McClure et al. 2000) and the maturation rates (b_2 - b_6 ; Table VI-13 of McClure et al. 2000). For convenience in comparing base and recent ocean harvest rates, NMFS estimated cumulative exploitation rates in the Draft Biological Opinion and presented these in the "Grand Summary" worksheet of each spreadsheet. The cumulative exploitation rate was defined according to Equation 18.

$$\text{(18)} \quad \text{Cumulative Exploitation} = (s_o * h_2) + (s_o^2 * (1-h_2)*(1-b_2)*h_3) + (s_o^3 * (1-h_2)*(1-b_2)*(1-h_3)*(1-b_3)*h_4) + (s_o^4 * (1-h_2)*(1-b_2)*(1-h_3)*(1-b_3)*(1-h_4)*(1-b_4)*h_5) + (s_o^5 * (1-h_2)*(1-b_2)*(1-h_3)*(1-b_3)*(1-h_4)*(1-b_4)*(1-h_5)*(1-b_5)*h_6)$$

The terms are as defined in the paragraph preceding Equation 18. The approach is easier to evaluate by examining Table C-13, which shows the annual accounting of fish that are harvested, maturing and returning to the Columbia River, and dying in the ocean as a result of other factors.

Changes in ocean harvest rates also affect the cumulative natural ocean survival rate. Table C-13 demonstrates that the latter rate changes from 41.2% with the base period harvest rates to 43.3% with current harvest rates. The change in the proportion of fish returning to the river mouth is a function of both the change in this term and the change in (1 - the cumulative harvest rate). By combining these terms, adults returning to the mouth of the Columbia River increased from 34.2% of the fish alive at the end of age-1 during the base period to 38% under current harvest rates. The combined change in (1 - cumulative ocean harvest rate) and cumulative natural ocean survival was included in all analyses as the effect of the change from base period to current ocean harvest rates.

NMFS characterized the recent SR fall chinook in-river harvest rate as the average 1993-through-1996, in-river harvest rates. These were obtained from Peters et al. (1999). The average harvest rate for recent years was 17.4%, compared to the base period average of 31.5%.

Table C-13. Worksheet showing the method of estimating annual ocean exploitation rate for SR fall chinook salmon.

A. Fall Chinook Base Period (1985-1996) Cumulative Ocean Exploitation Rate

Age	Fish Alive In Ocean at Start of Year	Natural Survival Rate	Harvest Rate	Maturity Rate		Fish Harvested	Fish to River	Fish That Died In Ocean
2	1000.0	0.8	0.024	0.0000		19.2	0.0	200.0
3	780.8	0.8	0.081	0.0815		50.6	46.8	156.2
4	527.3	0.8	0.188	0.6495		79.3	222.5	105.5
5	120.0	0.8	0.203	0.8633		19.5	66.1	24.0
6	10.5	0.8	0.219	1.0000		1.8	6.5	2.1
					Sum:	170.4	341.9	487.7
					Cumulative Rate:	0.170	0.342	0.488

Simplified Survival Rate: (1-0.17) * 0.412 = 0.342

Cumulative Non-Harvest Survival Rate: 0.412

B. Fall Chinook Current/Future (1993-1996) Cumulative Ocean Exploitation Rate

Age	Fish Alive In Ocean at Start of Year	Natural Survival Rate	Harvest Rate	Maturity Rate		Fish Harvested	Fish to River	Fish That Died In Ocean
2	1000.0	0.8	0.012	0.0000		9.6	0.0	200.0
3	790.4	0.8	0.047	0.0815		29.7	49.1	158.1
4	553.5	0.8	0.137	0.6495		60.7	248.2	110.7
5	133.9	0.8	0.184	0.8633		19.7	75.5	26.8
6	12.0	0.8	0.195	1.0000		1.9	7.7	2.4
					Sum:	121.6	380.5	498.0
					Cumulative Rate:	0.122	0.380	0.498

Simplified Survival Rate: (1-0.122) * 0.433 = 0.380

Cumulative Non-Harvest Survival Rate: 0.433

C.3.4.3 Changes Related to Implementing Mid-Columbia HCP

NMFS assumed that the Mid-Columbia HCP goals would be met at all five PUD projects in the near future, so this change in survival was included in analyses of all actions for UCR spring chinook and UCR steelhead. Estimates of expected change were obtained from the QAR analysis (Cooney 2000) and are summarized in Table C-14.

Table C-14. Expected changes in survival above Priest Rapids Dam as a result of achieving Mid-Columbia River HCP goals at all PUD projects.

Species	Life Stage	Base Period Survival	HCP Survival
UCR Spring Chinook	Egg-to-Smolt	0.050	0.053
	Juvenile Passage	0.662	0.804
	Adult Passage	0.860	No Change
UCR Steelhead	Egg-to-Smolt (20% Hatchery Sp. Effect.)	0.063	0.069
	Egg-to-Smolt (80% Hatchery Sp. Effect.)	0.038	0.042
	Juvenile Passage	0.550	0.690
	Adult Passage	0.859	No Change

C.3.5 Proportional Survival Change Associated With RPA

The only change from the analysis of the proposed action and the RPA was in the juvenile and adult hydrosystem passage survival. These survival rates were either modified in the Leslie matrices or in the incremental survival term for SR steelhead.

The expected changes in juvenile passage survival are described in Section 9.7.1 of the Draft Biological Opinion. SIMPAS model analyses of the RPA are described in

C.3.6 Proportional Survival Change Associated With Breaching

Breaching four Snake River dams will only affect survival of the Snake River ESUs. Therefore, effects of this action on UCR spring chinook and steelhead are identical to those estimated for the RPA. The estimation methods are therefore also identical.

For the Snake River ESUs, the general approach was identical to that applied to evaluating the effects of the RPA. Specific estimates of juvenile and adult survival differed, however, because the upper 210 km of the hydrosystem will be a free-flowing river section, while the lower four projects will remain in place and be operated according to the RPA. The estimates for the upper section reflect the survival rates that would be expected to occur after sediment transport stabilizes and riparian vegetation establishes itself in the breached section of the river. NMFS did not attempt to analyze the presumably lower survival rates that would occur during the transition period following breaching.

A second change from the RPA analysis was the addition of a new assumption regarding *EM*. For the other actions, *EM* was assumed to be unchanged from the base period *EM*. For breaching, however, NMFS included one hypothesis proposed by PATH (Marmorek et al. 1998), which specifies that *EM* will be eliminated following breaching of four of the eight FCRPS dams.

All other methods and assumptions were identical to those described for analysis of the RPA in Section C.3.5. Details of breaching analyses are found on the same worksheets as RPA analyses in the spreadsheets for the Snake River ESUs.

C.3.6.1 Juvenile Passage Survival Associated With Breaching

After a natural channel configuration has developed in the 210-km reach and riparian vegetation has become established, NMFS expects that juvenile survival rates will approximate the rates observed in free-flowing reaches above the head of Lower Granite pool. Estimates of survival from the Salmon River trap at Whitebird to Lower Granite Dam are available for wild spring chinook salmon during 1966 through 1968 (Raymond 1979) and for wild spring/chinook salmon and steelhead during 1993 through 1998 (Smith et al. 1998; Hockersmith et al. 1999; Smith et al. 2000). The estimates for both periods include survival through Lower Granite Reservoir. Those for the recent period also include survival past Lower Granite Dam. Using the methods described in Appendix C to factor out the reservoir and dam mortality, NMFS calculated an average per-km survival rate through the free-flowing stretch of 0.999689614 per km for spring chinook and 0.999656 per km for steelhead. Interannual variation was high (Annex 1; "Natural" worksheets in each spreadsheet). The average estimates can be expanded to survival through the entire 210-km reach, resulting in a mean reach survival of 92.2% for SR spring/summer chinook salmon and 93.0% for SR steelhead (worksheets "Natural" and "New Passage Input" in SR spring/summer chinook spreadsheets; worksheets "Natural" and "Passage, EM = [0, 0.709, 0.743]" in SR steelhead spreadsheet; Table 9.7-18 of the Draft Biological Opinion). These estimates compare to a range of 85 to 95% estimated by the PATH team (Marmorek et al. 1998). The PATH estimates ranged from historical Whitebird trap estimates (95%) to combined Whitebird and Imnaha trap estimates for the period 1993 through 1996 (85%).

The estimates of survival through the breached section of the Snake River were combined with estimates of survival through the four lower Columbia River projects under the RPA to derive an estimate of system survival after the drawdown transition period. SIMPAS estimates of SR spring/summer chinook survival through the four lower Columbia River projects are included in the "New Passage Input" of the spreadsheets. In-river survival from McNary pool to Bonneville dam ranged from 54 to 71%, depending upon WY. When survival through the free-flowing reach in the lower Snake River was combined with survival through the impounded reach in the lower Columbia River, system survival of SR spring/summer chinook salmon ranged from 50 to 70% (average = 60.9%, "New Passage Input" worksheet). Using a similar method for steelhead, system survival with breaching for juveniles from this ESU is expected to range from 36 to 71% (average = 61.8%, "Passage, EM = [0, 0.709, 0.743]" worksheets).

Empirical estimates of free-flowing reach survival for juvenile SR fall chinook salmon is more limited and difficult to interpret. The PATH participants used two methods to group and extrapolate recent PIT-tag survival estimates (Peters et al. 1999). The first (referred to as PATH Method 1 in spreadsheets) results in a free-flowing survival rate of 0.9978 per km, and the second (PATH Method

2) results in a rate of 0.9995 per km (Annex 1). NMFS finds that both methods are credible and that there is no basis for concluding that one better represents the best available scientific information than the other. Therefore, NMFS used both methods to establish a range of likely survival estimates. When expanded to the 210-km reach, Method 1 estimates an average survival of 63.0 versus 90.0% for Method 2 ("PassageNew" worksheet in fall chinook spreadsheet). Using a method similar to that applied to SR spring/summer chinook salmon, and SIMPAS estimates of the survival of fall chinook salmon through the lower Columbia reach ("PassageNew" worksheet), the system survival of juvenile Snake River fall chinook ranges from 7.2 to 31.7% (average = 24.4%) with Method 1 and from 10.3 to 45.3% (average = 34.8%) with Method 2. Method 1 was included in the Low direct and indirect juvenile hydrosystem survival estimates while Method 2 was included in the High estimates ("Grand Summary" worksheet).

C.3.6.2 Delayed Mortality Assumptions Associated With Breaching

Unlike the method used for other actions, NMFS included only one assumption about *EM* for breaching. Both High and Low estimates of effects included the assumption of *EM* equal to zero. This assumption actually created two extremely different effects of breaching on the survival and recovery indicator metrics. In the first case, *EM* is zero in both the base period and after breaching. Therefore, the expected change in survival from the base period to a future breaching action depends solely upon the changes in direct passage survival and the elimination of transportation-related delayed effects (depending upon the base period *D* estimate). This turns out to be a relatively small change in survival from the base period, compared to the second case. For the second case, *EM* is relatively high during the base period and is reduced to zero following breaching. The resulting increase in survival is greater than that in the first case. For all other actions, *EM* did not change between the base period and action implementation: if *EM* was zero in the base period, it was zero under the action; if *EM* was high during the base period, it was also high under the action. The resulting assumption sets are displayed in Table C-15.

C.3.6.3 Adult Passage Survival Associated With Breaching

After a natural channel configuration has developed in the 210-km reach and riparian vegetation has become established, NMFS expects that adult survival rates through the lower Snake River will approximate the rates observed in free-flowing reaches above the head of Lower Granite pool. Annex 1 described various approaches to determining the natural survival rate of adults through the FCRPS. NMFS considers the best estimate of adult spring/summer chinook survival following breaching to be identical to the survival rate expected to result from the RPA; i.e., survival through an impounded reach with all possible improvements short of breaching. The rationale for this conclusion is discussed in Annex 1. Therefore, estimates of adult survival through the combined breached and unbreached sections of the FCRPS were identical to the estimates generated for the RPA ("Adult Input" worksheet in each spreadsheet).

Table C-15. Comparison of Low and High aggregate assumptions for base period and breaching estimates of juvenile direct and indirect passage survival.

	Base Period		Four-Dam Breach	
ESU	***D***	***EM***	***D***	***EM***
SR Spring/Summer Chinook				
Low	Average 0.63 and 0.73	Average of 0.709 and 0.743	(Essentially 1.0 because no transportation)	0
High	Average 0.63 and 0.73	0	(Essentially 1.0 because no transportation)	0
SR Fall Chinook				
Low	0.24	0.19	(Essentially 1.0 because no transportation)	0
High	0.24	0	(Essentially 1.0 because no transportation)	0
SR Steelhead				
Low	Average 0.52, 0.58	Average of 0.709 and 0.743	(Essentially 1.0 because no transportation)	0
High	Average 0.52, 0.58	0	(Essentially 1.0 because no transportation)	0

C.4 Results

The sections that follow provide results corresponding to individual and aggregate assumption sets.

C.4.1 Results For Individual Assumption Sets

Tables C-A2-1 through C-A2-41 display results for each individual set of assumptions (water year, *D*, and *EM*) for each population. Assumptions about changes in survival in other life stages are incorporated, as described in Section C.3. For all populations except SR steelhead, the tables display the estimated annual population growth rate (λ), the proportional change from base period λ, and the proportional change from the base period per-generation survival expected from each action. These tables also display all of the matrix elements for each assumption set and the life-stage survival rates discussed in previous sections of this appendix. These tables are also available as worksheets in each Draft Biological Opinion spreadsheet. Specific references were provided in earlier sections.

For SR steelhead, Tables C-A2-40 through C-A2-43 of Annex 2 display the specific estimates of passage survival, including *D* and *EM*, for each action. These tables do not include the changes in other life stages or the incremental changes in survival from the base period. Those estimates are included in the summary tables described in Section C.4.2.

C.4.2 Results For Aggregate Assumption Sets

Aggregate assumption sets are the combinations of water years, *D*, and *EM* estimates that were aggregated into High and Low estimates of direct and indirect juvenile passage survival, as described in Section C.3. The changes in survival expected from each action and the comparison of those changes to the needed survival changes (Tables C-2 through C-5) are displayed in the "Grand Summary" worksheets of each spreadsheet. The first page of this worksheet displays the expected survival rates for base, current (proposed action), aggressive (RPA), and breach actions. The second page displays the range of needed changes from base-period survivals to meet the approximations of the acceptable probabilities described in Table C-1 for each of the five indicator metrics. The third page describes the expected change in survival from each action and any additional survival changes that are still needed to meet the goals. For SR spring/summer chinook and UCR spring chinook, the second and third pages are repeated for estimates of needed changes that are based on preliminary returns and projections beyond 1999. Finally, this worksheet includes a series of figures that display the lowest and highest estimates of the needed survival changes as horizontal bars, along with the lowest and highest expected changes from each action. These figures are presented as Figures C-A2-1 through C-A2-60 in Annex B.

Summaries of the best-case and worst-case effects of each action are presented in a series of tables in sections 6.3, 9.7.2, and 9.7.3 of the Draft Biological Opinion. The best case represented the highest estimate of the expected survival change resulting from each action against the lowest estimate of the survival change needed to achieve the probabilities described in Table C-1. The worst case paired the opposite extremes. All information in those tables was taken from the "Grand Summary" worksheets in each Draft Biological Opinion spreadsheet.

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Annex 1

Estimation of Hydrosystem Survival Under Natural Conditions

Application of the full mitigation indicator metric requires estimating of the survival rates that would occur in the absence of the FCRPS. This annex discusses the methods used to estimate natural survival rates for ESUs that use the FCRPS primarily as a juvenile and adult migration corridor. NMFS has not attempted to quantify survival rates for the spawning, incubation, and early rearing life stages of ESUs that use the FCRPS action area for these purposes. The Draft Biological Opinion qualitatively discusses those life stages with respect to the full mitigation indicator metric.

A1.1 Estimates of Juvenile Passage Survival

NMFS used a two-step method to estimate juvenile survival in the absence of the FCRPS. First, it determined the average survival rate (expressed as a function of distance) of the species of interest through a river reach that is similar to that expected in the lower Snake and lower Columbia rivers in the absence of the FCRPS. NMFS then expanded these rate estimates to represent the distance each ESU must traverse through the FCRPS.

The best available estimates for survival of yearling chinook salmon and steelhead through free-flowing river reaches came from wild PIT-tagged smolts captured and released at the Whitebird trap on the Salmon River and subsequently detected at Lower Granite Dam between 1993 and 1998 (Smith et al. 1998; Hockersmith et al. 1999; Smith et al. 2000a,b; Tables A1-1 and A1-2; and "Natural" worksheets in Draft Biological Opinion spreadsheets). These cumulative survival estimates included passage through the impounded Lower Granite Reservoir and Lower Granite Dam. NMFS estimated survival through Lower Granite Dam and the reservoir from direct estimates made from 1993 through 1995 (chinook), 1994 through 1996 (steelhead), and extrapolations for other years from Williams et al. (in review). NMFS divided the cumulative survival from Whitebird trap to Lower Granite Dam by the estimate of Lower Granite Reservoir and dam survival for each year to obtain an estimate of cumulative survival through the free-flowing reach (Tables A1-1 and A1-2).

The distance between the Whitebird trap and the head of Lower Granite pool is 181 km. Therefore, survival per-km through the free-flowing reach was the 181st root of the cumulative survival rate. For wild yearling chinook, this resulted in a mean estimated free-flowing reach survival rate of 0.99961/km. The corresponding mean survival rate for steelhead was 0.99966/km.

Similar estimates were also available for survival from traps upstream of Whitebird on the Salmon River and from the Imnaha River trap. Estimates of survival per km from these traps were consistently lower than estimates for fish released from the Whitebird trap (Tables A1-1 and A1-2; Paulsen 2000). NMFS did not incorporate the Imnaha trap or other Salmon River

Table A1-1. Summary of NMFS yearling chinook salmon free-flowing reach survival estimates.

	Surv Trap-LGR		Surv[a]	Surv Trap-Head Res[b]		Surv per km[b]	
	Imnaha	Salmon	LGR Res	Imnaha	Salmon	Imnaha	Salmon
1993	0.81	0.83	0.90	0.90	0.93	0.99887	0.99960
1994	0.76	0.79	0.92	0.83	0.86	0.99791	0.99919
1995	0.91	0.86	0.92	0.99	0.94	0.99984	0.99963
1996	0.81	0.82	0.90	0.91	0.92	0.99889	0.99951
1997	0.90	NA[c]	0.90	1.00	NA[c]	0.99995	NA[c]
1998	0.85	0.93	0.94	0.91	0.99	0.99897	0.99993
1999	0.88	0.91	0.94	0.94	0.97	0.99926	0.99982
Trap Mean	0.85	0.86		0.92	0.93	0.99910	**0.99961**
Std. Dev.	0.05	0.05		0.06	0.04	0.00069	0.00026

a. Williams et al. (In review).

b. Head of reservoir assumed at Snake River trap; see below for distances.

c. No wild chinook salmon tagged.

Notes: Material used in this table was taken from S. Smith (NMFS) June 12, 2000, trap.xls spreadsheet. "Salmon" refers to releases from Whitebird trap on the Salmon River; "Imnaha" refers to releases from the Imnaha River trap. Bold survival rate was used in all Draft Biological Opinion analyses.

	PTAGIS Rkm	km to LGR
Salmon Trap	522.303.103	181
Imnaha Trap	522.308.007	90
Snake Trap	522.23	
Lower Granite	522.17	

Table A1-2. Summary of NMFS yearling steelhead free-flowing reach survival estimates.

	Surv Trap-LGR		Surv[a]	Surv Trap-Head Res[b]		Surv per km[b]	
	Imnaha	Salmon	LGR Res	Imnaha	Salmon	Imnaha	Salmon
1993	0.76	0.83	0.91	0.83	0.91	0.99797	0.99948
1994	0.66	0.77	0.90	0.73	0.85	0.99645	0.99913
1995	0.84	0.89	0.91	0.92	0.98	0.99905	0.99988
1996	0.87	0.96	0.94	0.92	1.01	0.99905	1.00008
1997	0.90	NA[c]	0.92	0.97	NA[c]	0.99971	NA[c]
1998	0.86	0.89	0.90	0.96	0.99	0.99952	0.99997
1999	0.88	0.82	0.91	0.97	0.90	0.99963	0.99939
Trap Mean	0.82	0.86		0.90	0.94	0.99877	**0.99966**
Std. Dev.	0.09	0.07		0.09	0.06	0.00118	0.00037

a. Williams et al. (In review).

b. Head of reservoir assumed at Snake River trap; see below for distances.

c. No wild chinook salmon tagged.

Note: Material used in this table was taken from S. Smith (NMFS) June 12, 2000, trap.xls spreadsheet. "Salmon" refers to releases from Whitebird trap on the Salmon River; "Imnaha" refers to releases from the Imnaha River trap. Bold survival rate was used in all Draft Biological Opinion analyses.

	PTAGIS Rkm	km to LGR
Salmon Trap	522.303.103	181
Imnaha Trap	522.308.007	90
Snake Trap	522.225	
Lower Granite	522.171	

traps into the estimates of natural survival. Traps in the Salmon River above Whitebird and the Imnaha trap releases were not used in natural survival estimates for the following reasons:

! The other Salmon River trap estimates were already captured in the Whitebird to Lower Granite estimate, because it included fish from all of the tributaries caught at the upstream traps.

! The Whitebird estimate is through a river reach that is more similar to the reach below Lower Granite Dam (in terms of river width, depth, and flow characteristics) than are the reaches further up in the tributaries. The Imnaha trap is in a tributary habitat that is also less similar to the reach below Lower Granite Dam than is the Whitebird trap.

! The upstream traps are closer to spawning areas, so survival rates from those traps probably represent a culling process that would be greater than that included in the survival rate below Whitebird. To elaborate, culling may result from size, degree of smoltification, or river stretches through which the smolts migrated. The river reach from Whitebird to Lower Granite is more similar to the free-flowing lower Snake and lower Columbia than is the reach from Salmon River tributaries to Lower Granite. Imnaha trap estimates were not used because the trap is closer to the spawning grounds than is the Whitebird trap.

To test the hypothesis that survival is lower in reaches closer to spawning grounds than in reaches farther downstream, survival of Whitebird and Imnaha releases was compared in the reach between each trap and Lower Granite Dam and in two reaches below Lower Granite Dam (Tables A1-3 and A1-4). Survival between the Imnaha trap and Lower Granite Dam, expressed as a per-km rate, was much lower than that between the Whitebird trap and Lower Granite Dam (Tables A1-1 and A1-2), whereas survival estimates for the two traps were nearly identical when compared between Lower Granite Dam and Little Goose Dam and between Little Goose Dam and Lower Monumental Dam. This suggests that, after initial losses of fish occur, there are no inherent differences in smolt survival between stocks released at Imnaha and Whitebird. Thus, the Whitebird trap provides the best estimates of expected survival in downstream stretches of natural river.

Table A1-5 shows how the yearling chinook and yearling steelhead survival rates were expanded to approximate the natural survival rates of each chinook and steelhead ESU. NMFS first determined the maximum distance that any population within an ESU travels through the hydrosystem. The cumulative natural survival rate for an ESU was then the mean survival rate per km, raised to the power of the number of km traveled through the hydrosystem. For example, UCR spring chinook pass through 287 km of the FCRPS and are assumed to have the same natural survival rate as SR spring/summer chinook. Their expected natural survival through the FCRPS reach is 89.5% ($0.999614283^{286.9}$).

Table A1-3. Survival estimates for Whitebird trap (Salmon R.) spring/summer chinook releases and Imnaha trap spring/summer chinook releases.

	Surv LGR-LGO		Surv LGO-LMN		Surv LGR-LMN	
	Imnaha	Salmon	Imnaha	Salmon	Imnaha	Salmon
1993	0.78	0.87	NA	NA	NA	NA
1994	0.86	0.75	0.82	0.89	0.71	0.67
1995	0.92	0.91	0.97	1.00	0.90	0.91
1996	0.91	0.91	0.86	1.00	0.78	0.90
1997	0.99	NA	0.95	NA	NA	NA
1998	1.02	1.02	0.85	0.81	0.87	0.83
1999	0.98	0.95	0.91	0.93	0.89	0.88
Trap Mean	0.92	0.90	0.89	0.92	0.828	0.837
Std. Dev.	0.09	0.09	0.06	0.08	0.08	0.10

Note: These releases move through river reaches below Lower Granite Dam. Estimates from NMFS PIT-tag studies are described in text. From spreadsheet “trap.xls” prepared by S. Smith (NMFS).

Table A1-4. Survival estimates for Whitebird trap (Salmon R.) steelhead releases and Imnaha trap steelhead releases.

	Surv LGR-LGO		Surv LGO-LMN		Surv LGR-LMN	
	Imnaha	Salmon	Imnaha	Salmon	Imnaha	Salmon
1993	1.02	0.76	NA	NA	NA	NA
1994	0.82	0.81	0.74	0.73	0.60	0.59
1995	0.88	0.96	1.09	0.94	0.96	0.90
1996	0.87	0.87	1.00	1.25	0.87	1.09
1997	1.02	NA	0.83	NA	NA	NA
1998	1.00	0.87	0.82	0.77	0.82	0.67
1999	0.99	1.14	0.88	0.82	0.86	0.93
Trap Mean	0.94	0.90	0.89	0.90	0.823	0.835
Std. Dev.	0.08	0.13	0.13	0.21	0.13	0.20

Note: These releases move through river reaches below Lower Granite Dam. Estimates from NMFS PIT-tag studies are described in text. From spreadsheet “trap.xls” prepared by S. Smith (NMFS).

Table A1-5. Summary of mean per-km juvenile survival rates through free-flowing river reaches.

ESU	Mean Per-Km Survival	# Km	Mean Survival
Snake Sp/Sum CH	0.999614283	512	0.821
Snake SH	0.999656110	512	0.838
Snake Fall CH (Method A)	0.997800000	512	0.324
Snake Fall CH (Method B)	0.999500000	512	0.774
UCR Spring CH	0.999614283	287	0.895
UCR SH	0.999656110	287	0.906
MCR SH	0.999656110	287	0.906
LCR CH Yearlings	0.999614283	34.5	0.987
LCR CH Subs (Method A)	0.997800000	34.5	0.927
LCR CH Subs (Method B)	0.995000000	34.5	0.841
LCR SH	0.999656110	24.1	0.992

Note: Table data include rate expansion to distances currently traversed through the FCRPS. Mean survivals are the natural survival estimates used to evaluate the full mitigation standard.

Empirical estimates of free-flowing reach survival for juvenile SR fall chinook salmon is more limited and difficult to interpret. The PATH participants used two methods to group and extrapolate recent PIT-tag survival estimates (Peters et al. 1999). The first (designated Method A) results in a free-flowing survival rate of 0.9978 per km, and the second (designated Method B) in a rate of 0.9995 per km.

Method A was based on the premise that survival from release to Lower Granite for fish released at Pittsburgh Landing encompasses survival through the free-flowing Snake River (the 122 km from release to the head of Lower Granite Reservoir) and a ‘project’ survival through Lower Granite Reservoir and the dam. After the project survival is divided out of the total survival, the free-flowing survival remains. To estimate Lower Granite project survival, PATH used the mean survival through the two projects below Lower Granite: Little Goose and Lower Monumental.

To obtain the average for all release groups, PATH weighted each survival estimate by the proportion of the total run of wild fish that were sampled in the period that included the release date as its midpoint. In addition, each survival estimate was weighted by the inverse of the relative variance. The relative variance is defined as the variance divided by the estimated survival. This removes some of the bias of lower survivals having lower variance (S. Smith, NMFS, pers. comm. to PATH 1998). For this weighting, the variances were from survival through the entire segment (release to Lower Monumental), since all this information was used in the estimates. Both of these weights were normalized to add up to 1.0 so that neither weight would have more influence than the other. Separate estimates of survival through the free-flowing reach were made for each release (19 total) from 1995 to 1998. Each of these estimates was then weighted, and the geometric mean of all the estimates was computed. The resulting survival rate estimate was 0.9978 per km.

Peters et al. (1999) state that the Method B juvenile survival rate was estimated from NMFS’ reported survival rate estimates for PIT tagged fall chinook in 1998, 1997, and 1995 (Muir and Smith 1998, Muir et al. 1998). The value was computed by comparing survival rates from different points of release in the Snake River above the confluence of the Snake and Clearwater Rivers. The ratio of the survival rate estimate for the upstream release site (Pittsburgh Landing – ‘PL’) to that of the downstream release site (Billy Creek – 'BC') was used to derive free-flowing Snake River survival estimates. This ratio was calculated for each release group; then the release group estimates were averaged. The length of the PL- to BC-reach (81 km) was then used to obtain a per-km survival rate, which equaled 0.9995.

NMFS found that both methods were credible and that there was no basis for concluding that one better represented the best available scientific information. Therefore, NMFS used both methods to establish a range of likely natural survival estimates. When expanded to the 512-km reach, Method A estimates an average survival of 32.4% versus 77.4% for Method B (Table A1-5).

A1.2 Estimates of Adult Passage Survival

NMFS considered three methods for estimating expected survival of adults in the absence of the FCRPS. NMFS concluded that the third method described below was most reasonable, and that method was the only one applied in the Draft Biological Opinion.

A1.2.1 PATH Method

The PATH participants estimated free-flowing survival of wild SR spring/summer chinook salmon as 97% cumulative survival through the Snake River if four dams are breached (equivalent to 99% per project). Although the derivation of this estimate is not explicitly described in Marmorek et al. (1998) or Marmorek and Peters (1998a,b), personal communications indicate that it was obtained by applying the absolute difference in Bjornn's (1989) mean dam-count to redd-count ratios at Ice Harbor Dam for two periods, 1962 through 1968 and 1975 through 1988, to estimates of current adult passage survival through that reach. Ice Harbor was the furthest upstream FCRPS project during the first period. PATH interpreted the 9% difference (3% per project) between the mean ratios for each period as the mortality caused by the three dams that were constructed above Ice Harbor during the latter period (1975 through 1988). Extrapolating Bjornn's (1989) result from three dams to the four dams proposed to be breached, PATH estimated that adult survival would improve 12% if the four lower Snake River dams were breached. PATH estimated the current passage survival at 85%, based on conversion rates in Beamesderfer et al. (1998) and concluded that the survival rate through the four lower Snake River projects would be 97% (85% + 12%) following breaching.

The essential implication of this method is that PATH estimated a 99.24% per-project natural survival rate for adult spring/summer chinook salmon ($0.97^{(1/4)}$). PATH concluded that this same survival rate applies to SR fall chinook (Peters et al. 1999) without explanation. If NMFS applied this approach to estimates of natural survival through the entire FCRPS, it would conclude that adults of all SR ESUs have a natural survival rate of 94% through eight FCRPS projects, UCR and MCR ESUs have a natural survival rate through up to four FCRPS projects of 97%, and populations of LCR ESUs that spawn above Bonneville Dam have a natural survival rate of 99% through one project.

NMFS has several concerns regarding this approach. This method assumes that survival from the current location of the head of Lower Granite pool to the various spawning areas did not change between the two time periods described in Bjornn (1989) and that redd counts represented a constant fraction of total spawners in the Salmon, Grande Ronde, and Imnaha River systems during each period. Neither assumption was discussed or substantiated by PATH, and the assumption validity is questionable given the variation in more recent estimates, as described below. To apply the 9% change in survival to current survival, one must assume that there has been no change from adult survival during Bjornn's (1989) second period to the present. As described in Appendix C, NMFS believes that adult survival through the FCRPS has been relatively constant since 1980, but it has not drawn the same conclusion for the period beginning in 1975. NMFS has also concluded that adult survival is better described by radio-telemetry than by conversion rates. If the 3% per project survival improvement following dam removal was applied to the current SR spring/summer chinook adult survival estimate (0.972; Table 6.1-1 of Draft Biological Opinion), the natural survival rate would be slightly greater than 100%. Finally, a significant drawback of this method is the lack of comparable information for species other than SR spring/summer chinook. PATH assumed that the absolute estimate for spring/summer chinook should be applied to fall chinook (Peters et al. 1999). Given the lower current survival rate of fall chinook (Table 6.1-1 of Draft Biological Opinion), however, equally reasonable alternatives would have been to apply a 3% survival improvement per project to the current fall chinook survival rate or to conclude that the effect of dams on fall chinook cannot be inferred from the effects of dams on spring chinook.

A1.2.2 Direct Estimates of Free-flowing Reach Survival

A second method evaluates the survival of radio-tagged adults through free-flowing reaches above Lower Granite Dam, in a manner similar to that used to estimate juvenile survival. Bjornn et al. (1995) estimated adult loss of spring chinook salmon from Ice Harbor Dam to reference points in tributaries to the Snake River above Lower Granite Dam (Table A1-6). Bjornn et al. (1995) estimated survival from Ice Harbor to Lower Granite (footnotes to Table A1-6), and NMFS adjusted total survival rates to derive estimates of survival through the free-flowing reach above Lower Granite Dam. The resulting survival rate averaged 0.9994 per km, equal to 73.5% survival through the 512-km reach encompassing the entire hydrosystem. This is equivalent to a natural survival rate of 96% per-project, for eight projects.

NMFS also has concerns about this second approach, which may under-estimate survival of adults through free-flowing river sections. One potential problem is the degree to which radio-tagged adults migrating through free-flowing reaches above Lower Granite Dam represent adults that would be migrating through a free-flowing reach between Bonneville and Lower Granite. The experience of migrating 512 km past eight dams probably influences the survival upstream of Lower Granite Dam. Use of this method assumes that there is no effect of migrating 512 km and no delayed effects of passing eight dams. This method also assumes that the free-flowing river reaches above Lower Granite are comparable to the reaches between Bonneville and Lower Granite. The end points of the reaches were chosen to avoid inclusion of passage through spawning tributaries that clearly would not represent mainstem passage, but the degree to which the chosen reaches represent conditions below Lower Granite is debatable. One additional concern is that, as with the first method, this approach is not applicable to all species because radio-telemetry estimates are not available.

Table A1-6. Estimates of SR spring/summer chinook survival in free-flowing river sections to spawning stream entrance calculated by radio-telemetry (Bjornn et al. 1995).

YEAR	WILD/ HATCHERY	SURVIVAL FROM UPPER MOST DAM	REACH	UPPERMOST DAM PROJECT SURVIVAL	MAINLY RIVER SURVIVAL (1)	KM MAINLY RIVER	RIVER SURVIVAL/KM	4-POOL RIVER SURVIVAL/ 210 KM	BON-LGR RIVER SURVIVAL/512 KM	REFERENCE
1991	Run-at-Large Radio-tag	0.54	IHR to Spawning in Upper Salmon River (North Fork)	0.967	0.6187	**685.4**	0.9993	0.8632	0.6987	Bjornn et al. (1995), fish RT at IHR
1992	Run-at-Large Radio-tag	0.63	IHR to Spawning in Upper Salmon River (North Fork)	0.958	0.7482	**685.4**	0.9996	0.9194	0.8148	Bjornn et al. (1995), fish RT at IHR
1993	Run-at-Large Radio-tag	0.77	IHR to Spawning in Upper Salmon River (North Fork)	0.98	0.8370	**685.4**	0.9997	0.9389	0.8576	Bjornn et al. (1995), fish RT at JDA
1991	Run-at-Large Radio-tag	0.54	IHR to Spawning in Middle Fork Salmon River	0.967	0.6187	**624.4**	0.9992	0.8453	0.6638	Bjornn et al. (1995), fish RT at IHR
1992	Run-at-Large Radio-tag	0.63	IHR to Spawning in Middle Fork Salmon River	0.958	0.7482	**624.4**	0.9995	0.9003	0.7741	Bjornn et al. (1995), fish RT at IHR
1993	Run-at-Large Radio-tag	0.77	IHR to Spawning in Middle Fork Salmon River	0.98	0.8370	**624.4**	0.9997	0.9389	0.8576	Bjornn et al. (1995), fish RT at JDA
1991	Run-at-Large Radio-tag	0.54	IHR to Spawning in South Fork Salmon River	0.967	0.6187	**561.4**	0.9991	0.8277	0.6306	Bjornn et al. (1995), fish RT at IHR
1992	Run-at-Large Radio-tag	0.63	IHR to Spawning in South Fork Salmon River	0.958	0.7482	**561.4**	0.9995	0.9003	0.7741	Bjornn et al. (1995), fish RT at IHR
1993	Run-at-Large Radio-tag	0.77	IHR to Spawning in South Fork Salmon River	0.98	0.8370	**561.4**	0.9997	0.9389	0.8576	Bjornn et al. (1995), fish RT at JDA
1991	Run-at-Large Radio-tag	0.54	IHR to Spawning in Imnaha River	0.967	0.6187	**322.4**	0.9985	0.7297	0.4637	Bjornn et al. (1995), fish RT at IHR
1992	Run-at-Large Radio-tag	0.63	IHR to Spawning in Imnaha River	0.958	0.7482	**322.4**	0.9991	0.8277	0.6306	Bjornn et al. (1995), fish RT at IHR
1993	Run-at-Large Radio-tag	0.77	IHR to Spawning in Imnaha River	0.968	0.8370	**322.4**	0.9994	0.8816	0.7354	Bjornn et al. (1995), fish RT at JDA

YEAR	WILD/ HATCHERY	SURVIVAL FROM UPPER MOST DAM	REACH	UPPERMOST DAM PROJECT SURVIVAL	MAINLY RIVER SURVIVAL (1)	KM MAINLY RIVER	RIVER SURVIVAL/KM	4-POOL RIVER SURVIVAL/ 210 KM	BON-LGR RIVER SURVIVAL/512 KM	REFERENCE
1991	Run-at-Large Radio-tag	0.54	IHR to Spawning in Grande Ronde River	0.967	0.6187	**277.4**	0.9983	0.6996	0.4185	Bjornn et al. (1995), fish RT at IHR
1992	Run-at-Large Radio-tag	0.63	IHR to Spawning in Grande Ronde River	0.958	0.7482	**277.4**	0.9990	0.8105	0.5991	Bjornn et al. (1995), fish RT at IHR
1993	Run-at-Large Radio-tag	0.77	IHR to Spawning in Grande Ronde River	0.98	0.8370	**277.4**	0.9994	0.8816	0.7354	Bjornn et al. (1995), fish RT at JDA
						Combined Weighted Mean Run-at-Large Estimate	0.9994	0.8816	0.7354	

(1) **SURVIVAL FROM UPPERMOST DAM** / **UPPERMOST DAM PROJECT SURVIVAL** = **MAINLY RIVER SURVIVAL**

Note: This material comes from a spreadsheet and table prepared by C. Pinney (Corps of Engineers) for Federal agency performance standards report.

<u>Bjornn et al. (1995) notes</u>: Survival IHR ladder exit to LGR ladder exit = 90% in 1993 and 85% in 1992 (similar to untagged); success of passage IHR tailrace to LGR forebay = 81.3% in 1992 and 87% in 1993; success passage IHR tailrace to upper end LGR pool = 78.7% in 1992 and 75% in 1991; relative distribution of spr/sum chinook into tributaries of SR basin in 1993 = 5% Tuccannon River, 21% Clearwater River, 4% Snake River upstream of Lewiston, 11% Grande Ronde, 8% Imnaha, 51% Salmon rivers (natal tributaries).

A1.2.3 Qualitative Appraisal of Adult Natural Survival Rate

NMFS considers the best estimate of adult SR spring/summer chinook survival following breaching to be intermediate to estimates derived from the two methods described above. The survival rate expected to result from the RPA represents survival through an impounded reach with all possible improvements short of breaching. The estimate of adult survival, when the RPA is fully implemented, is 98% per project. This estimate is intermediate to the survival rate estimated by the first and second methods (96% and 99% per project, respectively).

In addition to the similarity of estimates of survival through impounded and unimpounded reaches, as described above, one of the reasons for concluding that adult survival under the RPA is equal to natural survival is the migration rates through the impounded FCRPS, which are very similar to those through unimpounded reaches. Studies supporting this observation are reviewed in NMFS' All-H Paper (2000). Another reason is the description in NMFS (2000) of factors currently causing mortality of adults through the FCRPS and the Draft Biological Opinion's provision to ameliorate these sources of mortality through the RPA. One of the primary factors causing apparent, and to some extent actual, mortality of adults is fallback NMFS (2000) describes studies indicating that this problem is particularly severe for the Bradford Island fish ladder at Bonneville Dam, where fallback rates may be as high as 15%. Structural and operational measures in the RPA are expected to reduce inadvertent fallback and related mortalities (Draft Biological Opinion Section 9.7.1.2). Another factor described in NMFS (2000) is occasional adult gas bubble disease during conditions of high gas supersaturation. The RPA also calls for a gas abatement program to reduce gas supersaturation. In general, the RPA is expected to reduce the current adult mortality rate, which is already estimated to be relatively low, by a relative 25%.

One advantage of this method for estimating the survival of SR spring/summer chinook salmon is that it is directly applicable to other ESUs, whereas the other two methods are not. Therefore, estimates of adult survival for all ESUs are as described in Draft Biological Opinion Table 9.7-2. The expected survival rates are 72.1% for SR fall chinook salmon, 85.1% for SR steelhead, and 85.1% for SR sockeye salmon.

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Annex 2

Selected Tables and Figures From Spreadsheets

Appendix C references 11 spreadsheets that NMFS used to estimate the effects of actions in the June 27, 2000, Draft Biological Opinion. These spreadsheets are available as Excel files that can be downloaded at http://www.nwr.noaa.gov/1salmon/salmesa/fedrec.htm. Some of the key tables and figures are reproduced in this annex for those who do not have the software needed to view the spreadsheets. These tables and figures are referenced in Appendix C.

Briefly, the tables display the life-stage survivals, fecundities, and maturation rates applied in equations in Appendix C. For all ESUs except SR steelhead, they were set up as matrices to estimate annual and per-generation population growth rates. Columns represent different actions and assumption sets, while rows represent survival rates and elements of the matrix. With respect to actions, “current” represents the proposed action, and “aggressive” represents the RPA. For SR steelhead, the worksheets used to estimate passage survival rates and resulting proportional changes are included. Matrices representing the entire life cycle were not produced for this ESU.

The figures in this annex summarize results over ranges of assumptions. Goals are represented as horizontal lines, and best- and worst-case estimates of action effects are displayed relative to the goals.